US011383513B2

(12) United States Patent
Kamijima et al.

(10) **Patent No.: US 11,383,513 B2**

(45) **Date of Patent: Jul. 12, 2022**

(54) **LIQUID DISCHARGING APPARATUS, HEAD CONTROL UNIT, AND HEAD UNIT**

(71) Applicant: **SEIKO EPSON CORPORATION**, Tokyo (JP)

(72) Inventors: **Masayuki Kamijima**, Ina (JP); **Masahiro Koiwai**, Matsumoto (JP)

(73) Assignee: **SEIKO EPSON CORPORATION**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 196 days.

(21) Appl. No.: **16/750,109**

(22) Filed: **Jan. 23, 2020**

(65) **Prior Publication Data**

US 2020/0238687 A1 Jul. 30, 2020

(30) **Foreign Application Priority Data**

Jan. 24, 2019 (JP) JP2019-010398

(51) **Int. Cl.**
B41J 2/045 (2006.01)

(52) **U.S. Cl.**
CPC ***B41J 2/04541*** (2013.01); ***B41J 2/04581*** (2013.01)

(58) **Field of Classification Search**
CPC B41J 2202/20; B41J 2/04541; B41J 2/04581; B41J 2/04588; B41J 2/04593; B41J 2/04596; B41J 29/393
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,137,508 A * 10/2000 Gaarder B41J 29/02 347/50
6,357,859 B1 * 3/2002 Klees B41J 29/393 347/50
6,523,920 B2 * 2/2003 Wade B41J 2/17553 347/19
6,715,857 B2 * 4/2004 Coffey B41J 2/14072 347/37
8,210,668 B2 * 7/2012 Espinoza-Ibarra B41J 2/16579 347/86
2002/0080218 A1 * 6/2002 Kaga B41J 2/01 347/104

(Continued)

FOREIGN PATENT DOCUMENTS

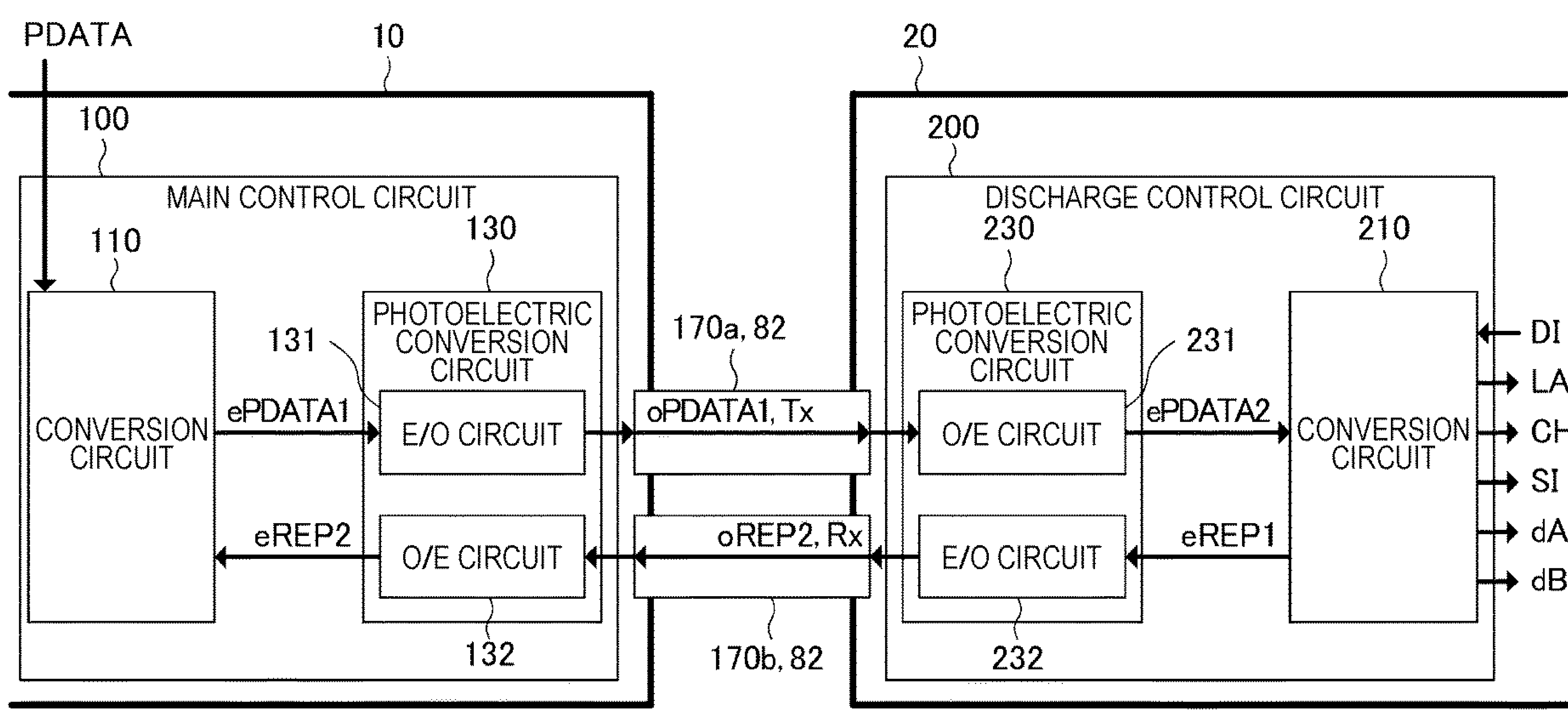
JP 2008-183845 A 8/2008

Primary Examiner — John Zimmermann
(74) *Attorney, Agent, or Firm* — Oliff PLC

(57) **ABSTRACT**

In a liquid discharging apparatus, a head control unit, which controls an operation of a head unit, includes a first conversion circuit that converts an image signal input from an outside into a first electric signal, a first photoelectric conversion circuit that converts the first electric signal into an optical signal, the head unit, which discharges a liquid, includes a second photoelectric conversion circuit that converts the optical signal into a second electric signal, a second conversion circuit that converts the second electric signal into a discharge control signal for controlling discharge of a liquid. The first conversion circuit performs a first conversion process of converting the image signal into the first electric signal without depending on a discharge information, and the second conversion circuit performs a second conversion process of converting the second electric signal into the discharge control signal by using the discharge information.

7 Claims, 14 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

2006/0214985	A1*	9/2006	Endo	B41J 11/0095 347/14
2020/0130391	A1*	4/2020	Kamijima	B41J 2/17509

* cited by examiner

FIG. 1

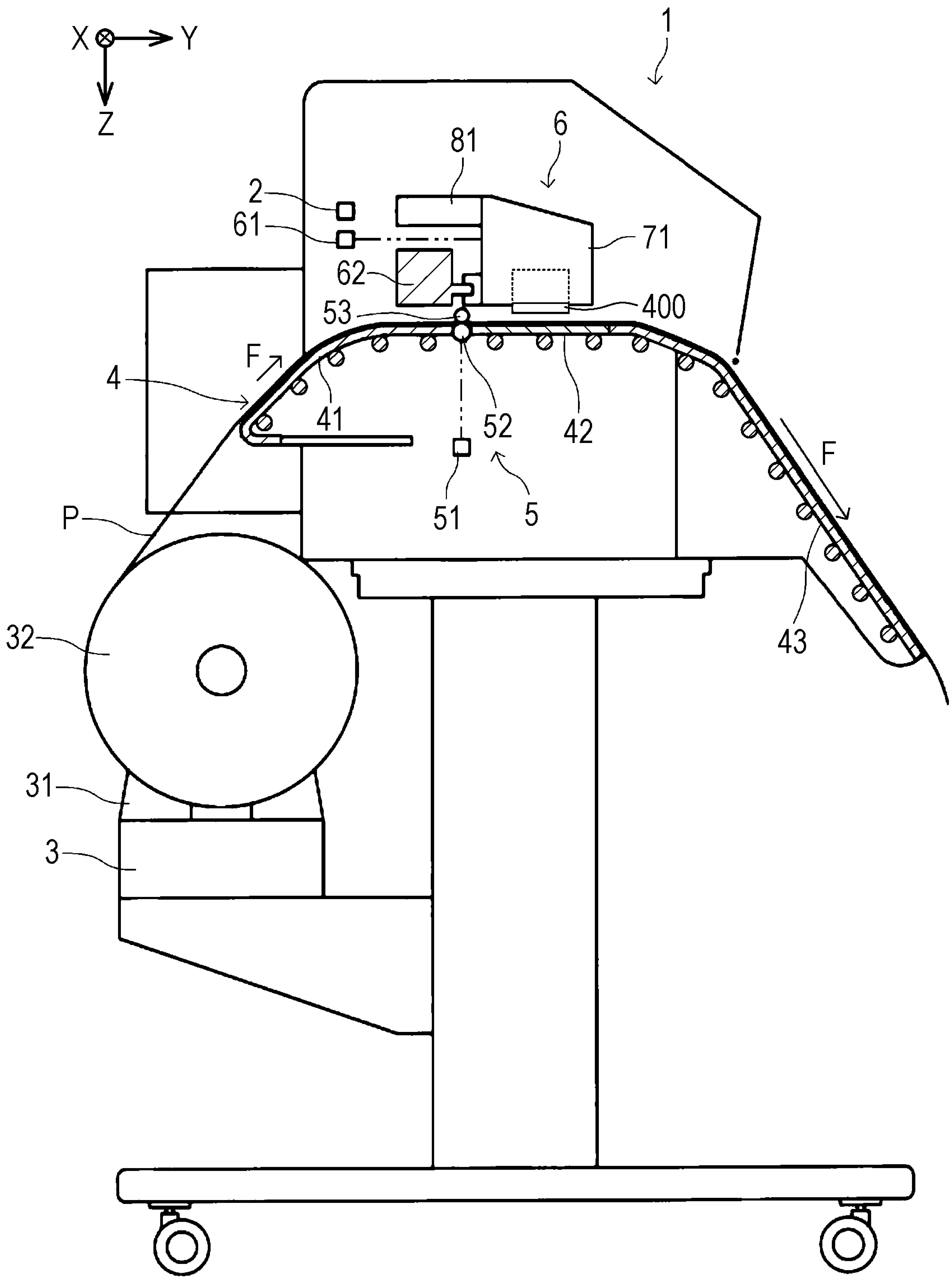


FIG. 2

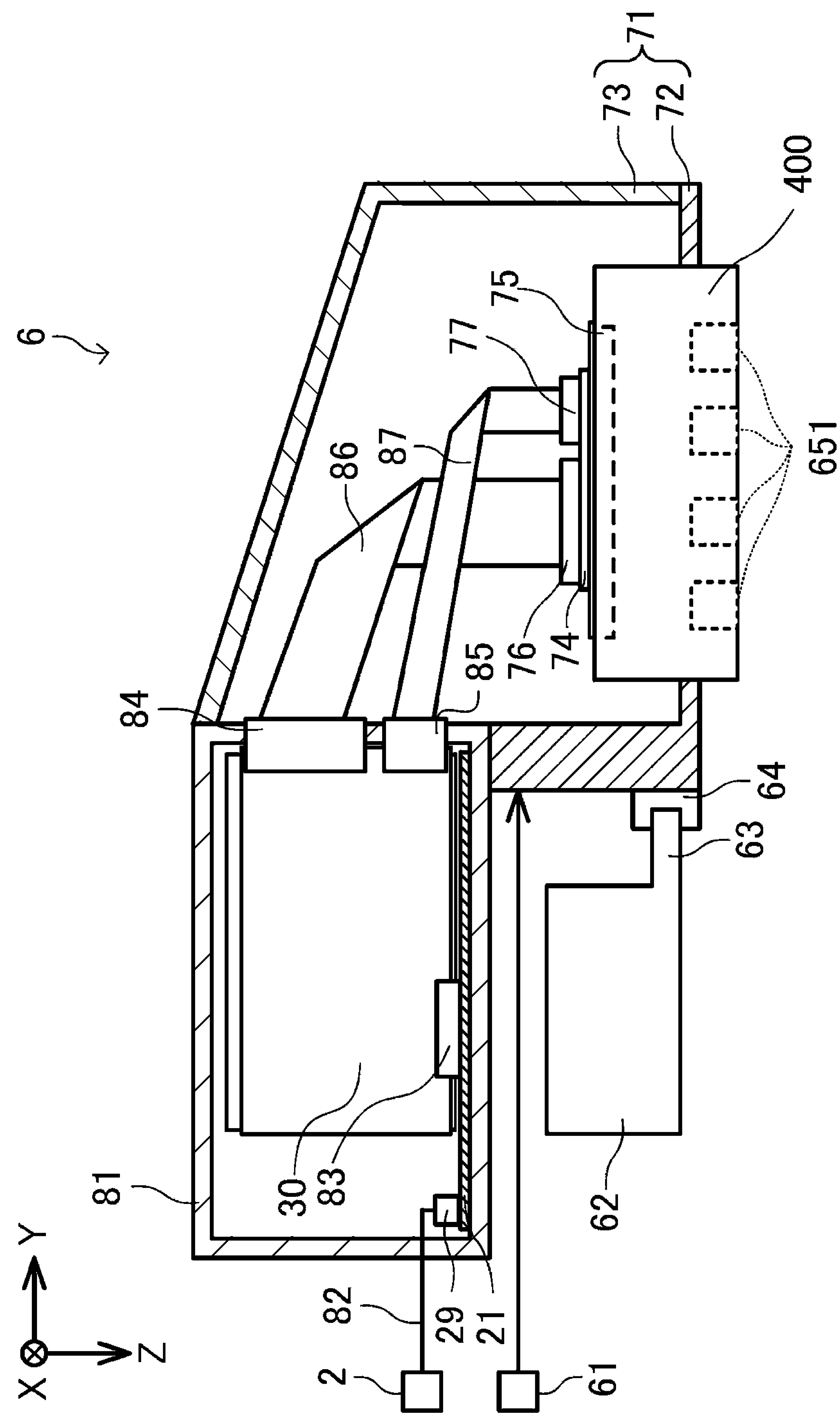

6
71
72
73
400
75
77
651
86
87
84
85
76
74
64
63
62
81
30
83
82
29
21
2
61
X
Y
Z

FIG. 3

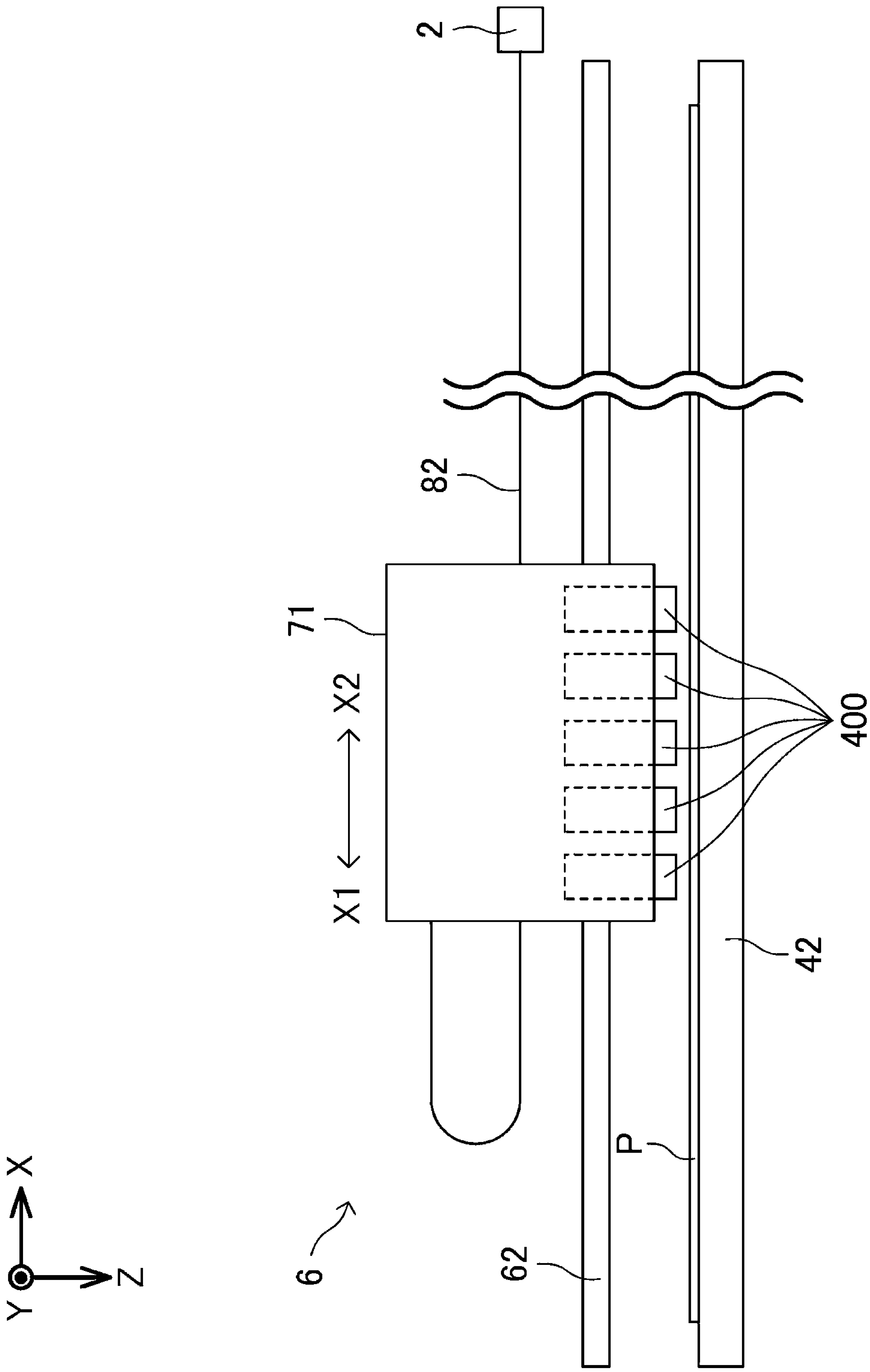


FIG. 4

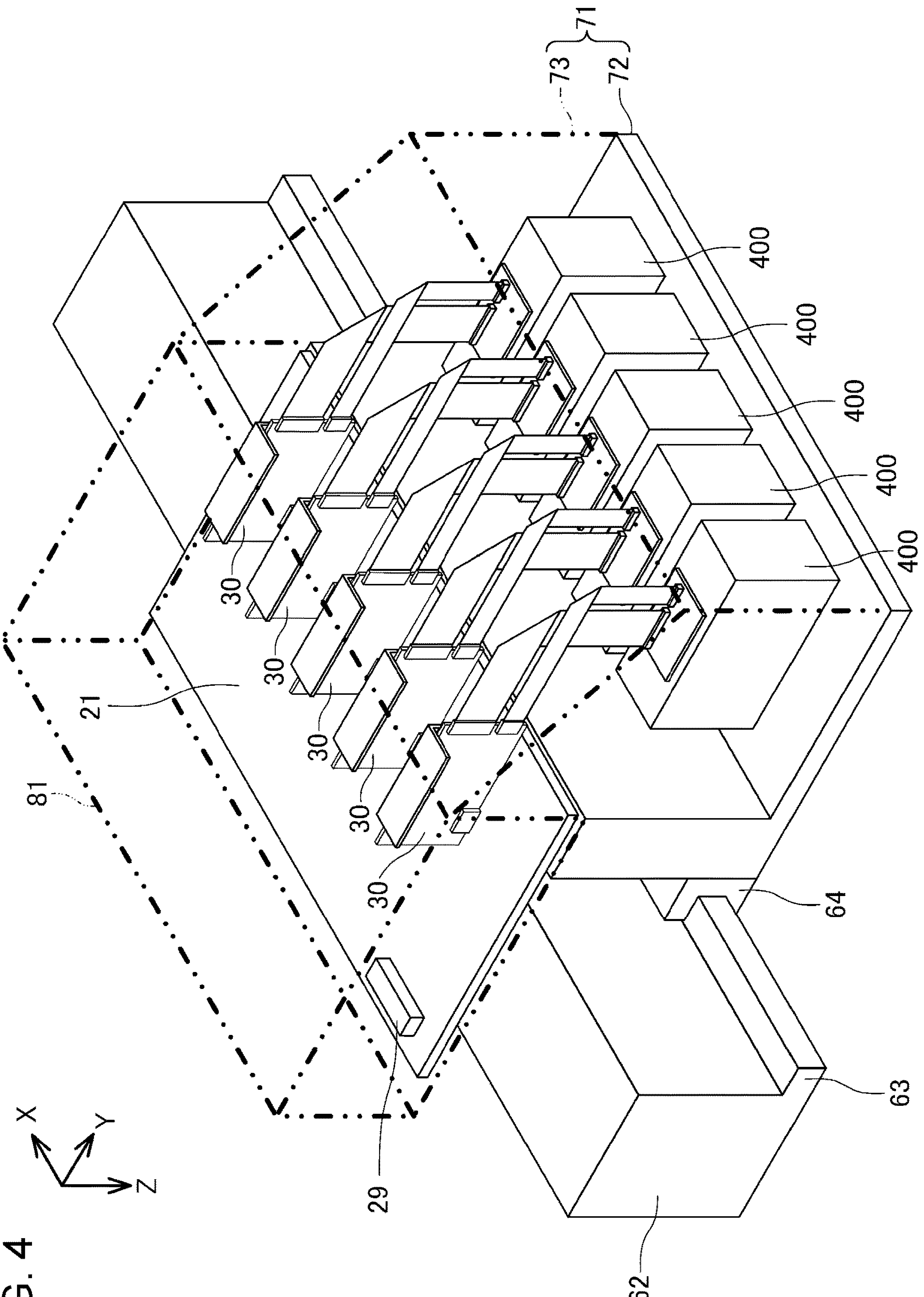


FIG. 5

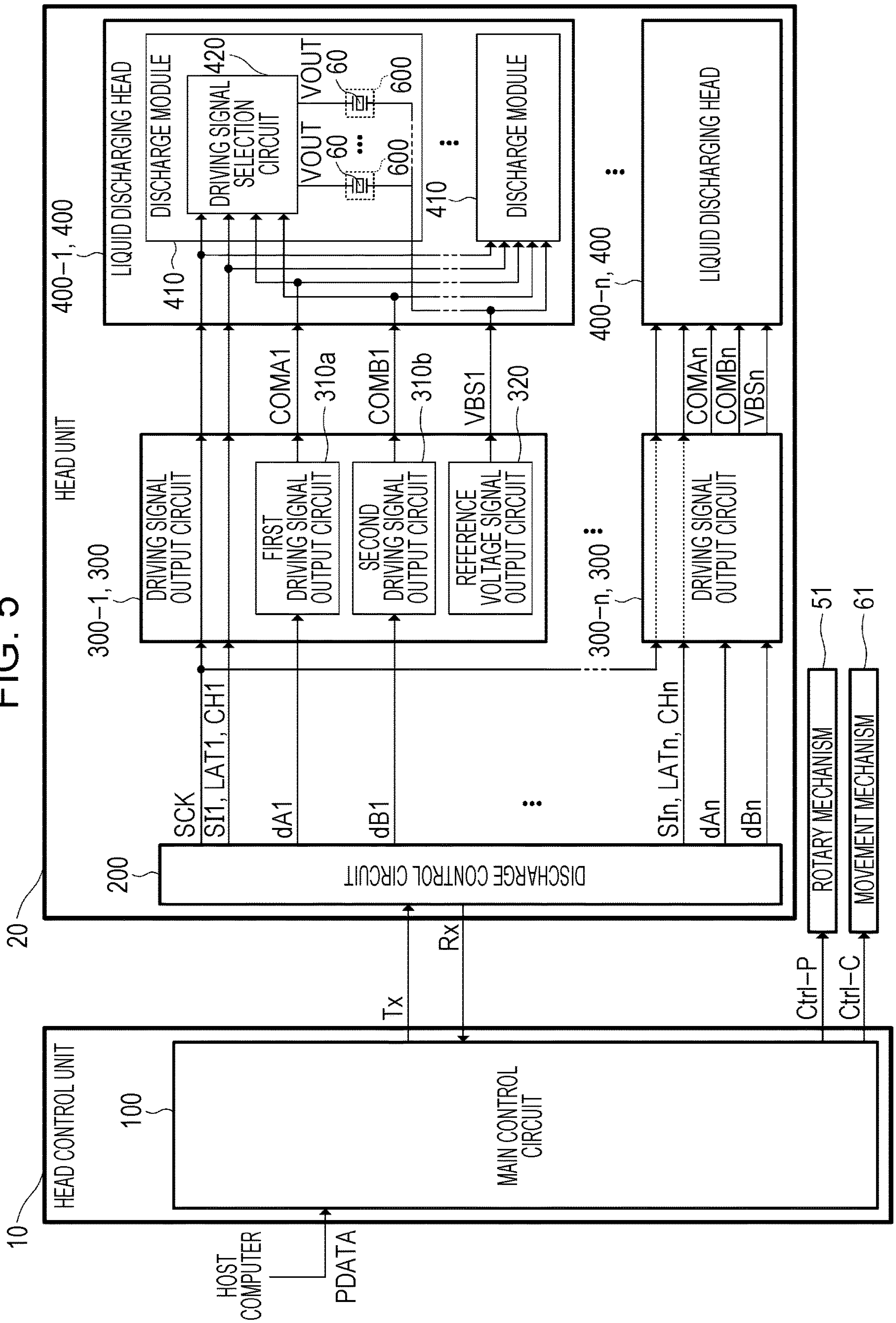

HEAD UNIT
20
HEAD CONTROL UNIT
10
100
MAIN CONTROL CIRCUIT
HOST COMPUTER
PDATA
Tx
Rx
Ctrl-P
Ctrl-C
ROTARY MECHANISM
51
MOVEMENT MECHANISM
61
200
DISCHARGE CONTROL CIRCUIT
SCK
SI1, LAT1, CH1
dA1
dB1
SIn, LATn, CHn
dAn
dBn
300-1, 300
DRIVING SIGNAL OUTPUT CIRCUIT
FIRST DRIVING SIGNAL OUTPUT CIRCUIT
SECOND DRIVING SIGNAL OUTPUT CIRCUIT
REFERENCE VOLTAGE SIGNAL OUTPUT CIRCUIT
310a
310b
320
COMA1
COMB1
VBS1
300-n, 300
DRIVING SIGNAL OUTPUT CIRCUIT
COMAn
COMBn
VBSn
400-1, 400
LIQUID DISCHARGING HEAD
410
DISCHARGE MODULE
420
DRIVING SIGNAL SELECTION CIRCUIT
VOUT
60
600
410
DISCHARGE MODULE
400-n, 400
LIQUID DISCHARGING HEAD

FIG. 6

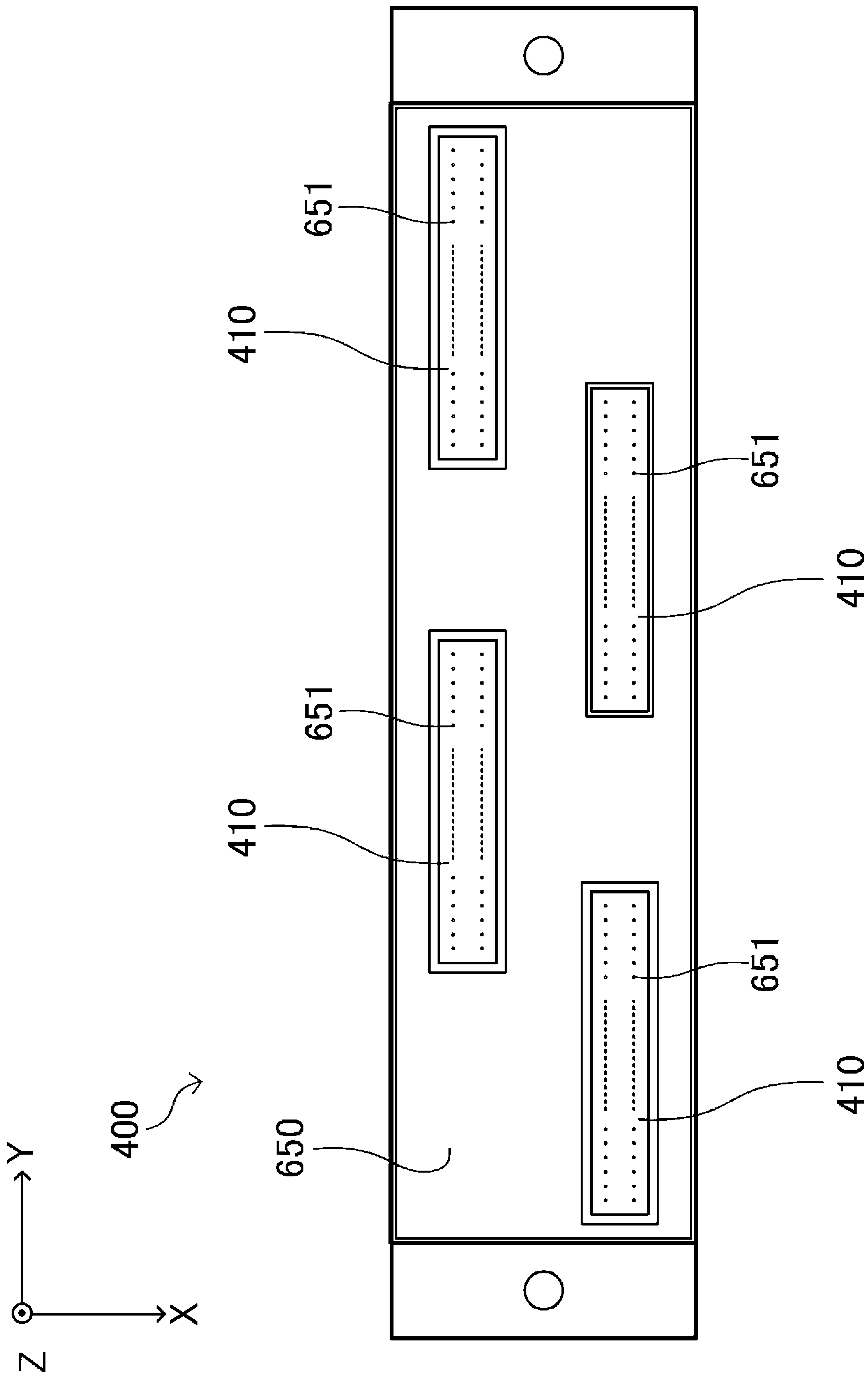


FIG. 7

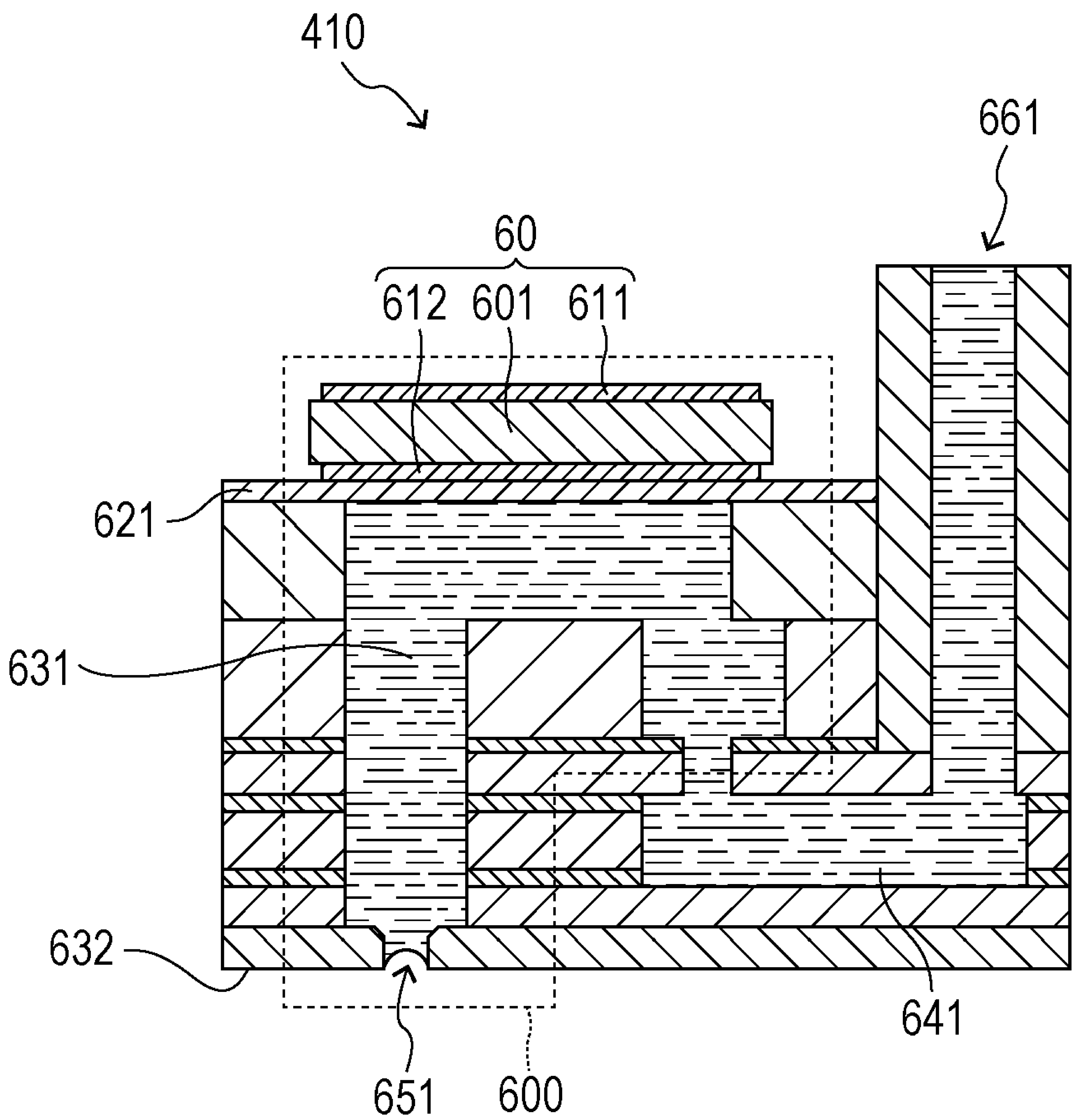


FIG. 8

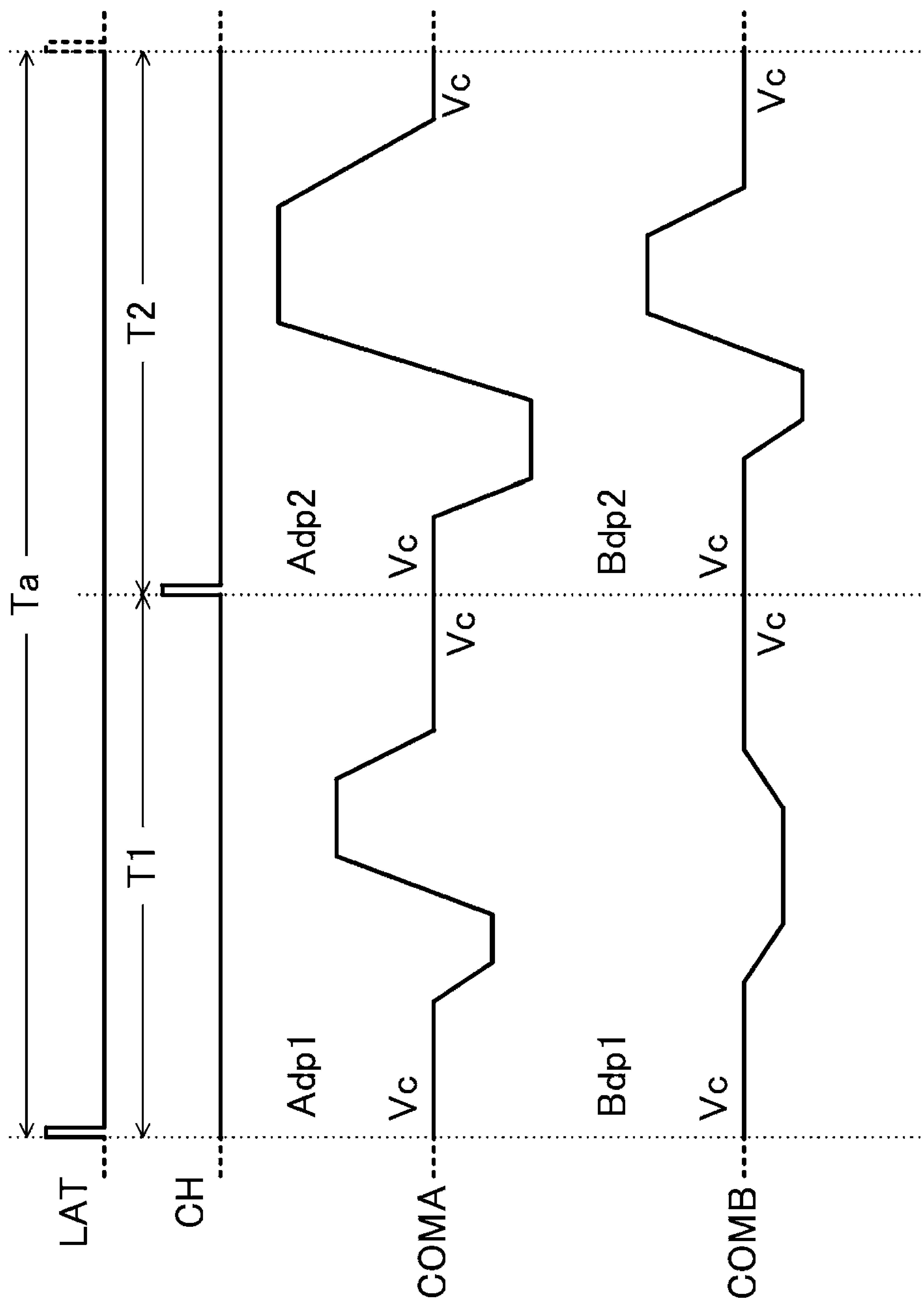

LAT
CH
COMA
COMB
Ta
T1
T2
Adp1
Adp2
Bdp1
Bdp2
Vc
Vc
Vc
Vc
Vc
Vc
Vc
Vc

FIG. 9

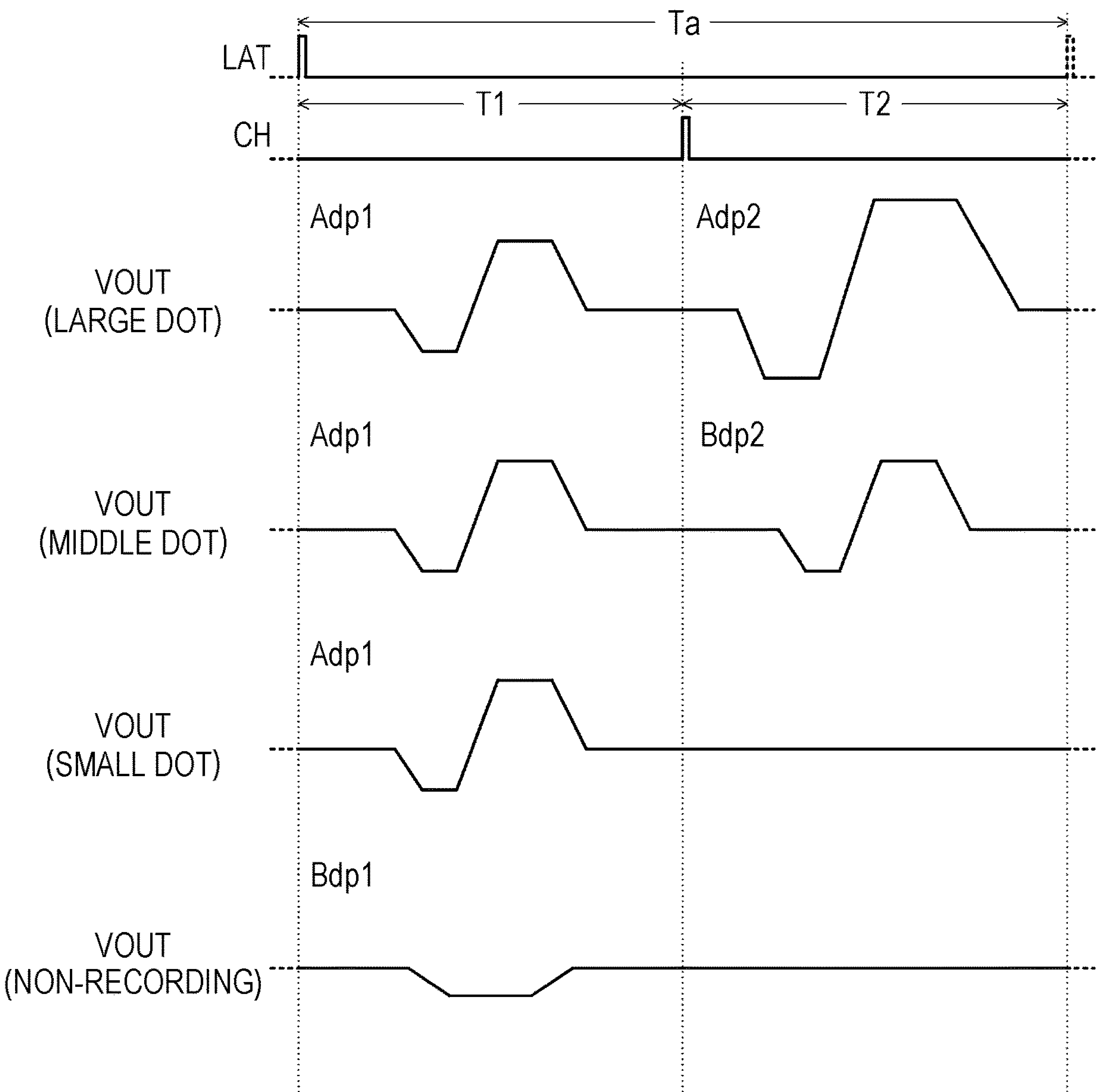

Ta
LAT
T1
T2
CH
Adp1
Adp2
VOUT
(LARGE DOT)
Adp1
Bdp2
VOUT
(MIDDLE DOT)
Adp1
VOUT
(SMALL DOT)
Bdp1
VOUT
(NON-RECORDING)

FIG. 10

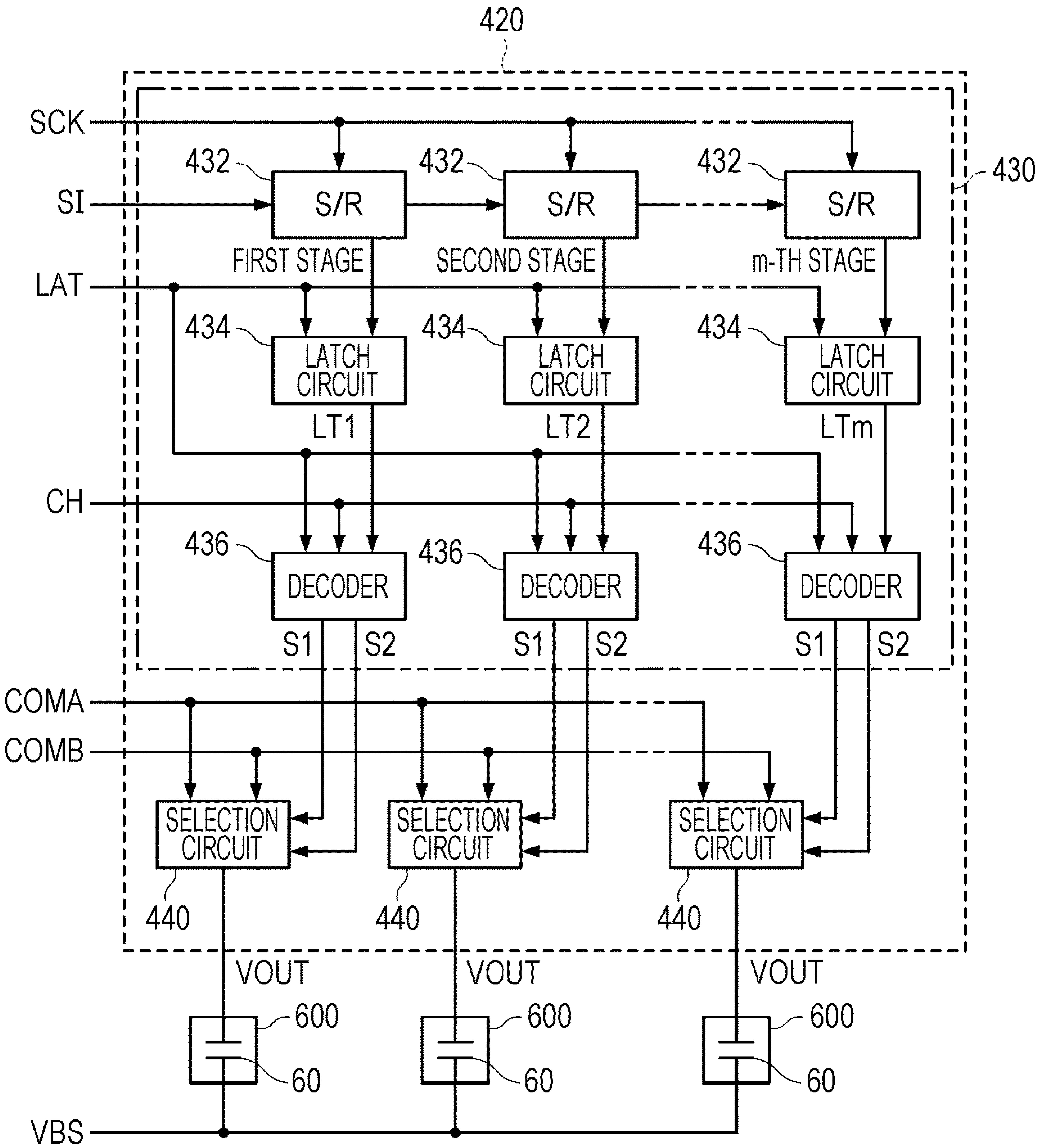

420
430
SCK
SI
LAT
CH
COMA
COMB
VBS
432
S/R
FIRST STAGE
SECOND STAGE
m-TH STAGE
434
LATCH CIRCUIT
LT1
LT2
LTm
436
DECODER
S1
S2
SELECTION CIRCUIT
440
VOUT
600
60

FIG. 11

[SIH, SIL]		[1, 1] LARGE DOT	[1, 0] MIDDLE DOT	[0, 1] SMALL DOT	[0, 0] NON-RECORDING
S1	T1	H	H	H	L
	T2	H	L	L	L
S2	T1	L	L	L	H
	T2	L	H	L	L

FIG. 12

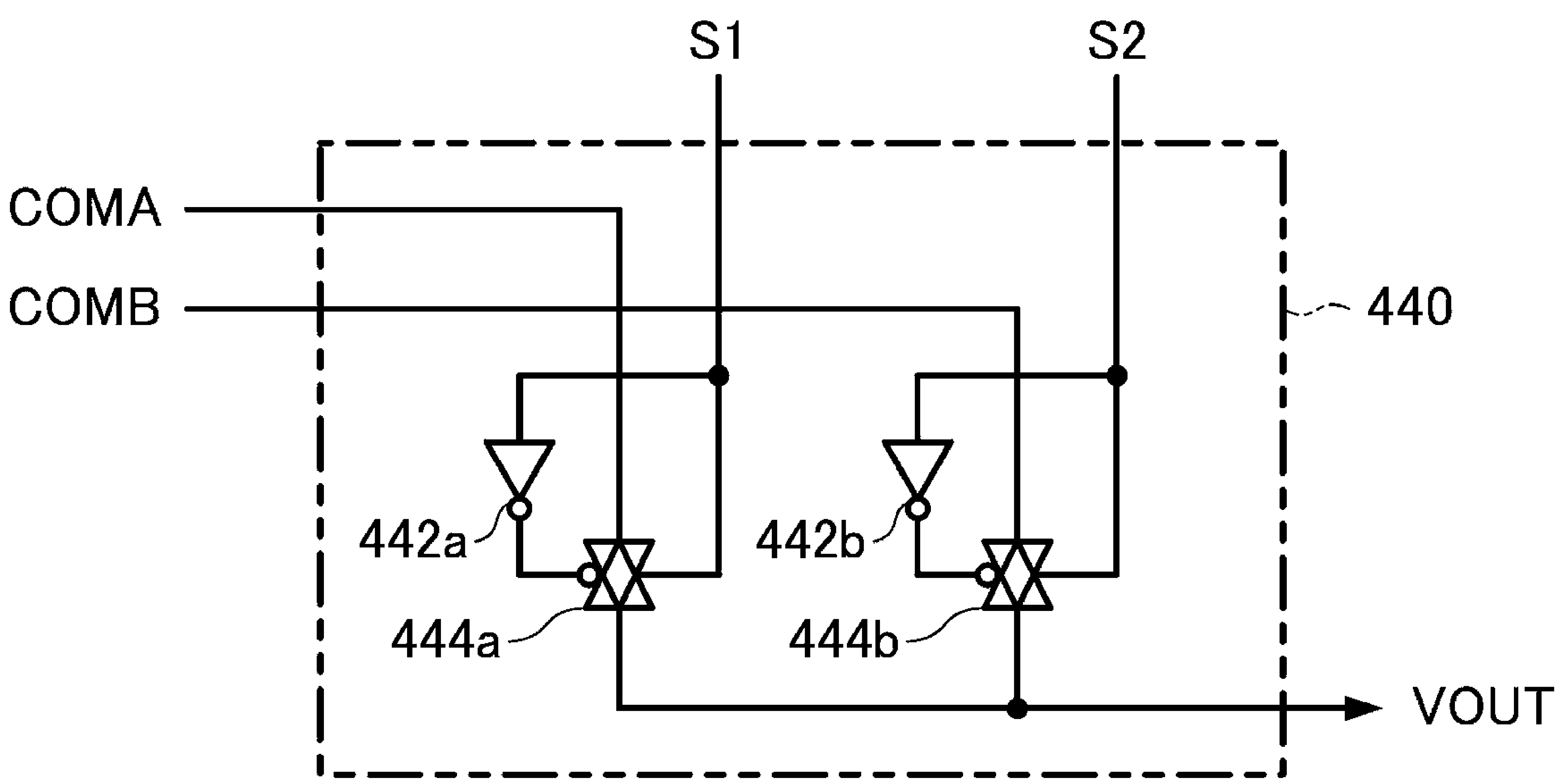


FIG. 13

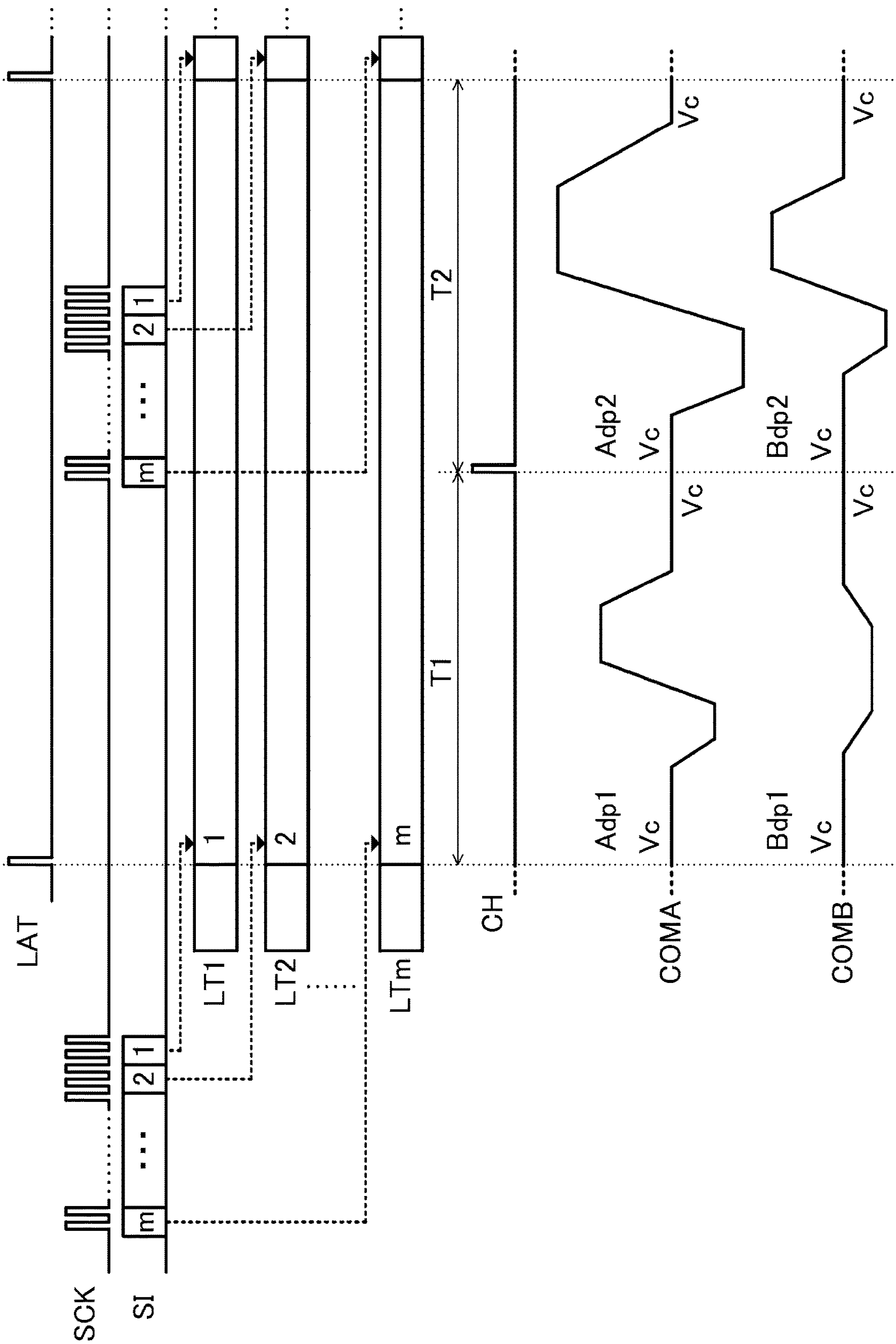

LAT
SCK
SI
m
2
1
LT1
LT2
LTm
Ta
T1
T2
CH
COMA
COMB
Adp1
Adp2
Bdp1
Bdp2
Vc

FIG. 14

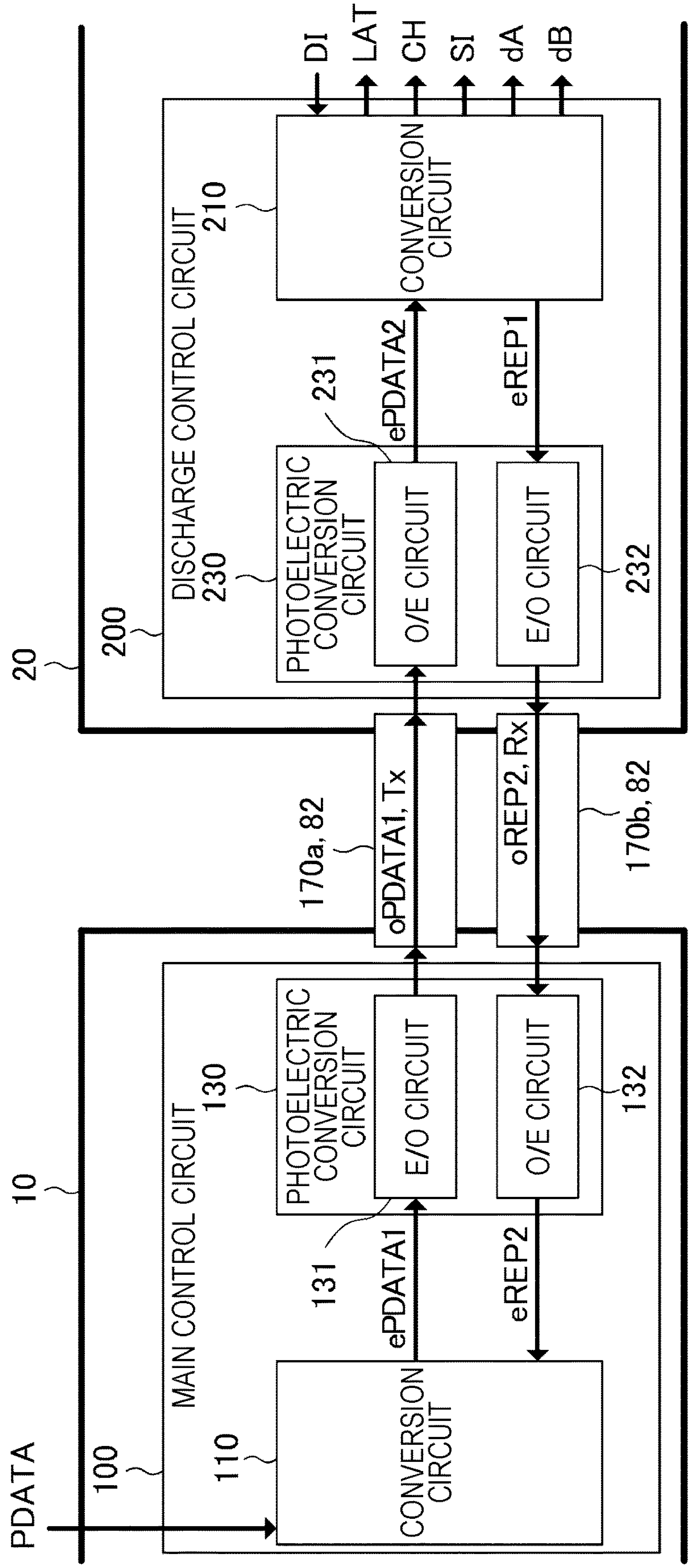
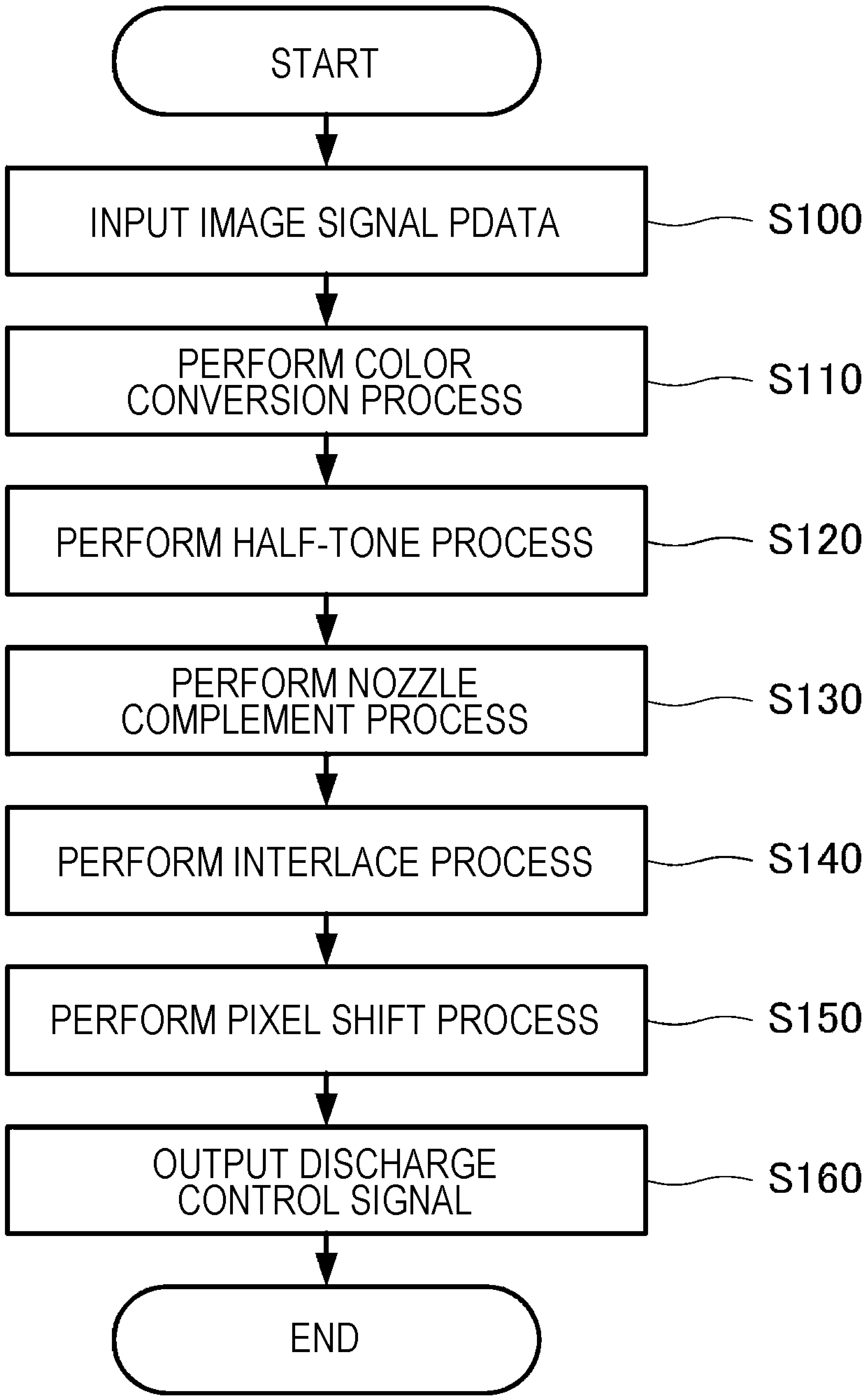

PDATA
10
100
110
CONVERSION CIRCUIT
MAIN CONTROL CIRCUIT
ePDATA1
131
eREP2
130
PHOTOELECTRIC CONVERSION CIRCUIT
E/O CIRCUIT
O/E CIRCUIT
132
oPDATA1, Tx
170a, 82
oREP2, Rx
170b, 82
20
200
DISCHARGE CONTROL CIRCUIT
230
PHOTOELECTRIC CONVERSION CIRCUIT
O/E CIRCUIT
E/O CIRCUIT
232
231
ePDATA2
eREP1
210
CONVERSION CIRCUIT
DI
LAT
CH
SI
dA
dB

FIG. 15


START
INPUT IMAGE SIGNAL PDATA
S100
PERFORM COLOR CONVERSION PROCESS
S110
PERFORM HALF-TONE PROCESS
S120
PERFORM NOZZLE COMPLEMENT PROCESS
S130
PERFORM INTERLACE PROCESS
S140
PERFORM PIXEL SHIFT PROCESS
S150
OUTPUT DISCHARGE CONTROL SIGNAL
S160
END

LIQUID DISCHARGING APPARATUS, HEAD CONTROL UNIT, AND HEAD UNIT

The present application is based on, and claims priority from JP Application Serial Number 2019-010398, filed Jan. 24, 2019, the disclosure of which is hereby incorporated by reference herein in its entirety.

BACKGROUND

1. Technical Field

The present disclosure relates to a liquid discharging apparatus, a head control unit, and a head unit.

2. Related Art

In an ink jet printer as an example of a liquid discharging apparatus, a technique has been known which prints an image or a document on a medium by propagating a control signal, which is generated by a control circuit or the like provided on a main body of the ink jet printer, to a print head (printing head) which includes nozzles for discharging ink, and by controlling discharge timing of the ink based on the control signal. In the liquid discharging apparatus, the control signal supplied to the print head is propagated between a main body of the liquid discharging apparatus and the print head.

For example, JP-A-2008-183845 discloses a technique for controlling discharge timing of ink from nozzles included in a printing head mounted on a carriage by generating a printing data signal for controlling discharge of the ink in a printer control portion provided in a main body of a printer, converting the generated printing data signal into an optical signal, and propagating the optical signal from the printer control portion to the carriage.

The signal for controlling the discharge of the ink from the nozzles included in the print head is generated by performing various processes, such as a color conversion process, a half-tone process, an interlace process, and a nozzle complement process, with respect to image data input from an outside of the liquid discharging apparatus. In the various processes, the interlace process and the nozzle complement process are performed based on a signal corresponding to information of the print head. Therefore, as in JP-A-2008-183845, when the printing data signal generated in the main body of the liquid discharging apparatus is converted into the optical signal and the optical signal is propagated to the print head, it is necessary to convert the information of the print head into the optical signal and to propagate the optical signal from the print head to the main body of the liquid discharging apparatus. However, in optical communication in which the optical signal is propagated, conversion time is necessary for conversion from an electric signal into an optical signal and conversion from an optical signal to an electric signal. Therefore, there is a possibility that time is required for generation of the printing data, and thus there is room for improvement from a viewpoint of advancement of a control speed of the liquid discharging apparatus.

SUMMARY

According to an aspect of the present disclosure, there is provided a liquid discharging apparatus including a head unit that discharges a liquid from a nozzle, and a head control unit that controls an operation of the head unit, in

which the head control unit includes a first conversion circuit that converts an image signal, which includes image data input from an outside, into a first electric signal, and a first photoelectric conversion circuit that converts the first electric signal into an optical signal, the head unit includes a second photoelectric conversion circuit that converts the optical signal into a second electric signal, a second conversion circuit that converts the second electric signal into a discharge control signal for controlling discharge of a liquid from the nozzle, and a liquid discharging head that includes a driving element, which is driven based on the discharge control signal, and that discharges a liquid from the nozzle in accordance with drive of the driving element, the first conversion circuit performs a first conversion process of converting the image signal into the first electric signal without depending on a discharge information of a liquid discharged from the liquid discharging head, and the second conversion circuit performs a second conversion process of converting the second electric signal into the discharge control signal by using the discharge information.

In the liquid discharging apparatus, the discharge information may include information which indicates whether or not to discharge a liquid from the nozzle.

In the liquid discharging apparatus, the first conversion process may include a color conversion process of converting color information corresponding to a hue of the image data included in the image signal into color information corresponding to a hue of a liquid discharged from the nozzle.

In the liquid discharging apparatus, the first conversion process may include a binarization process of converting the image signal into a signal which indicates whether or not a liquid corresponding to a pixel included in the image data is discharged.

In the liquid discharging apparatus, the first electric signal may be a signal acquired by performing the binarization process on a signal based on the image signal.

In the liquid discharging apparatus, the second conversion process may include a nozzle correspondence process of converting the second electric signal into a signal which indicates whether or not a liquid corresponding to the nozzle is discharged.

According to another aspect of the present disclosure, there is provided a head control unit, which controls an operation of a head unit that discharges a liquid from a nozzle, the head control unit including a first conversion circuit that converts an image signal, which includes image data input from an outside, into a first electric signal, and a first photoelectric conversion circuit that converts the first electric signal into an optical signal, in which the first conversion circuit performs a first conversion process of converting the image signal into the first electric signal without depending on a discharge information of a liquid discharged from the head unit.

According to another aspect of the present disclosure, there is provided a head unit, which discharges a liquid from a nozzle based on a signal input from a head control unit, the head unit including a second photoelectric conversion circuit that receives an optical signal input from the head control unit, and converts the optical signal into a second electric signal, a second conversion circuit that converts the second electric signal into a discharge control signal for controlling discharge of a liquid from the nozzle, and a liquid discharging head that includes a driving element, which is driven based on the discharge control signal, and that discharges a liquid from the nozzle in accordance with drive of the driving element, in which the second conversion circuit performs a second conversion process of converting the second electric signal into the discharge control signal by using a discharge information of a liquid discharged from the liquid discharging head.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view illustrating a configuration of a liquid discharging apparatus.

FIG. **2** is a side view illustrating a peripheral configuration of a printing portion of the liquid discharging apparatus.

FIG. **3** is a front view illustrating the peripheral configuration of the printing portion of the liquid discharging apparatus.

FIG. **4** is a perspective view illustrating the peripheral configuration of the printing portion of the liquid discharging apparatus.

FIG. **5** is a block diagram illustrating an electrical configuration of the liquid discharging apparatus.

FIG. **6** is a diagram illustrating a configuration of an ink discharge surface.

FIG. **7** is a diagram illustrating a schematic configuration of one of a plurality of discharge portions.

FIG. **8** is a diagram illustrating examples of waveforms of driving signals COMA and COMB.

FIG. **9** is a diagram illustrating examples of waveforms of a driving signal VOUT.

FIG. **10** is a diagram illustrating a configuration of a driving signal selection circuit.

FIG. **11** is a table illustrating decoding content in a decoder.

FIG. **12** is a diagram illustrating a configuration of a selection circuit.

FIG. **13** is a diagram for illustrating an operation of the driving signal selection circuit.

FIG. **14** is a diagram illustrating configurations of a head control unit and a head unit.

FIG. **15** is a flowchart illustrating a conversion processing method for converting an image signal PDATA into a discharge control signal.

DESCRIPTION OF EXEMPLARY EMBODIMENTS

Hereinafter, exemplary embodiments of the present disclosure will be described with reference to the accompanying drawings. The used drawings are for convenience of description. The embodiments described below do not wrongfully limit the scope of the present disclosure as set forth in the claims. Further, not all of configurations described below are necessarily essential configuration requirements of the present disclosure.

1. Outline of Liquid Discharging Apparatus

A configuration of a liquid discharging apparatus **1** according to the present embodiment will be described with reference to FIGS. **1** to **4**.

FIG. **1** is a side view illustrating a configuration of a liquid discharging apparatus **1**. FIG. **2** is a side view illustrating a peripheral configuration of a printing portion **6** of the liquid discharging apparatus **1**. FIG. **3** is a front view illustrating the peripheral configuration of the printing portion **6** of the liquid discharging apparatus **1**. FIG. **4** is a perspective view illustrating the peripheral configuration of the printing portion **6** of the liquid discharging apparatus **1**.

As illustrated in FIG. **1**, the liquid discharging apparatus **1** includes a delivery portion **3** that delivers a medium P, a support portion **4** that supports the medium P, a transport portion **5** that transports the medium P, the printing portion **6** that performs printing on the medium P, and a control portion **2** that controls these configurations.

In the following description, the width direction of the liquid discharging apparatus **1** is referred to as an X direction, the depth direction of the liquid discharging apparatus **1** is referred to as a Y direction, and the height direction of the liquid discharging apparatus **1** is referred to as a Z direction. Further, a direction in which the medium P is transported is referred to as a transport direction F. The X direction, the Y direction, and the Z direction are perpendicular to each other. Further, the transport direction F is a direction which intersects the X direction.

The control portion **2** is fixed to an inside of the liquid discharging apparatus **1** to generate various signals for controlling the liquid discharging apparatus **1** and to output the generated signals to corresponding various configurations.

The delivery portion **3** includes a holding member **31**. The holding member **31** rotatably holds a roll body **32** on which the medium P is wound and stacked. The holding member **31** holds different kinds of media P and roll bodies **32** having different dimensions in the X direction. Further, in the delivery portion **3**, as the roll body **32** is rotated in one direction, the medium P unwound from the roll body **32** is delivered to the support portion **4**.

The support portion **4** includes a first support portion **41**, a second support portion **42**, and a third support portion **43**, which constitute a transport path of the medium P from an upstream to a downstream in the transport direction F. The first support portion **41** guides the medium P delivered from the delivery portion **3** toward the second support portion **42**. The second support portion **42** supports the medium P on which printing is performed. Further, the third support portion **43** guides the printed medium P toward the downstream in the transport direction F.

The transport portion **5** includes a transport roller **52** that applies a transport force to the medium P, a driven roller **53** that presses the medium P against the transport roller **52**, and a rotary mechanism **51** that drives the transport roller **52**.

The transport roller **52** is disposed beneath the transport path of the medium P in the Z direction, and the driven roller **53** is disposed on the transport path of the medium P in the Z direction. The rotary mechanism **51** is configured with, for example, a motor and a reduction gear. Further, in the transport portion **5**, as the transport roller **52** rotates in a state in which the medium P is nipped by the transport roller **52** and the driven roller **53**, the medium P is transported in the transport direction F.

As illustrated in FIGS. **2** to **4**, the printing portion **6** includes a carriage **71**, a guide member **62**, a movement mechanism **61**, and a heat dissipating case **81**.

The carriage **71** includes a carriage main body **72** and a carriage cover **73**, and is provided to reciprocate along the X direction in a state of facing the medium P. The carriage main body **72** forms an approximately L-shape when viewed from the X direction. The carriage cover **73** is detachably provided with respect to the carriage main body **72**. Further, an enclosed space is formed when the carriage cover **73** is attached to the carriage main body **72**. At a lower portion of the carriage main body **72**, five liquid discharging heads **400** are mounted at regular intervals in the X direction. Each of the liquid discharging heads **400** includes a lower end portion provided to protrude outward from a lower surface of the carriage main body **72**. A plurality of nozzles **651** for discharging the ink, as an example of a liquid, to the medium P are formed on a lower surface of the liquid discharging head **400**.

The guide member **62** extends along the X direction. Further, on the guide member **62**, the carriage **71** is supported to reciprocate along the X direction. Specifically, the guide member **62** includes a guide rail portion **63** extending from a lower portion of a front surface of the guide member **62** in the X direction. Further, the carriage **71** has a carriage support portion **64** at a lower portion of a rear surface of the carriage **71**. The carriage support portion **64** is supported to slide on the guide rail portion **63**. Therefore, the carriage **71** is coupled to reciprocate along the guide member **62**.

The movement mechanism **61** includes a motor and a reduction gear. Further, the movement mechanism **61** controls normal rotation and reverse rotation of the motor, and converts a rotational force of the motor into a moving force in the X direction of the carriage **71**. Therefore, the carriage **71** reciprocates along the X direction in a state in which the five liquid discharging heads **400**, five driving circuit boards **30**, and a discharge control circuit board **21** are mounted. Further, the movement mechanism **61** may adjust a position in the Z direction of the carriage **71** by controlling the motor and the reduction gear. Therefore, even when the medium P which has different thickness is used, it is possible to adjust a distance between the liquid discharging head **400** and the medium P, and thus it is possible to increase landing accuracy of the ink which lands on the medium P.

The heat dissipating case **81** has an approximately rectangular parallelepiped shape in which the discharge control circuit board **21** and the five driving circuit boards **30** are accommodated. A front end portion of the heat dissipating case **81** is fixed to an upper end portion of the rear portion of the carriage **71**. That is, the discharge control circuit board **21** and the five driving circuit boards **30** are mounted on the carriage **71** via the heat dissipating case **81**.

A connector **29** is provided on the discharge control circuit board **21**. A plurality of cables **82** for coupling the control portion **2** to the discharge control circuit board **21** are coupled to the connector **29**. That is, the cables **82** are provided between the discharge control circuit board **21**, which is mounted on the carriage **71** that reciprocates in the X direction, and the control portion **2**, which is fixed to the liquid discharging apparatus **1**, for communication, and the cables **82** propagate various signals. Further, the five driving circuit boards **30** are installed upward the discharge control circuit board **21** in the Z direction and are provided in parallel in the X direction. The discharge control circuit board **21** and each of the driving circuit boards **30** are connected through a connector **83** such as a Board to Board (B to B) connector.

Connectors **84** and **85** are provided at a front end portion of each of the five driving circuit boards **30**. Each of the connectors **84** and **85** is exposed from a front surface of the heat dissipating case **81**. One end of a cable **86** is coupled to the connector **84**, and one end of a cable **87** is coupled to the connector **85**.

Further, a connection board **74** is provided on an upper surface of each of the five liquid discharging heads **400**. The connection board **74** is electrically coupled to the liquid discharging head **400** via a connector **75** such as a B to B connector. Connectors **76** and **77** are provided on the connection board **74**. Another end of the cable **86** is coupled to the connector **76**, and another end of the cable **87** is coupled to the connector **77**. Therefore, the five driving circuit boards **30** and the five relevant liquid discharging heads **400** are electrically coupled to each other.

In the description with reference to FIGS. **1** to **4**, description is performed such that the liquid discharging apparatus **1** includes the five driving circuit boards **30** and the five liquid discharging heads **400**. However, the number of driving circuit boards **30** and the number of liquid discharging heads **400** are not limited to five.

As above, in the liquid discharging apparatus **1**, the various signals, which are generated by the control portion **2** fixed to a main body of the liquid discharging apparatus **1**, are input to various configurations including the driving circuit board **30** and the liquid discharging head **400**, which are mounted on the carriage **71** provided to be reciprocated, via the cable **82**. Further, the carriage **71** reciprocates along the X direction, which is the scanning direction, under the control of the movement mechanism **61**, the medium P is transported along the transport direction F under the control of the rotary mechanism **51**, and the liquid discharging head **400** discharges the ink along the Z direction which is an ink discharge direction. Therefore, an image is formed on the medium P.

2. Electrical Configuration of Liquid Discharging Apparatus

Subsequently, an electrical configuration of the liquid discharging apparatus **1** will be described. FIG. **5** is a block diagram illustrating the electrical configuration of the liquid discharging apparatus **1**. As illustrated in FIG. **5**, the liquid discharging apparatus **1** includes a head control unit **10** and a head unit **20**.

The head control unit **10** includes a main control circuit **100** included in the above-described control portion **2**, and controls an operation of the head unit **20**.

The main control circuit **100** outputs, to the head unit **20**, a transmission signal Tx, which includes a signal acquired by performing various processes or the like on the image signal PDATA supplied from a not-shown host computer. Details of the processes performed on the image signal PDATA by the main control circuit **100** will be described later.

Further, the main control circuit **100** generates a control signal Ctrl-P for controlling transport of the medium P, and outputs the control signal Ctrl-P to the rotary mechanism **51**. The rotary mechanism **51** controls rotation of the above-described transport roller **52** by controlling the above-described motor and the reduction gear in accordance with the control signal Ctrl-P, and transports the medium P. Further, the main control circuit **100** generates a control signal Ctrl-C for controlling movement of the carriage **71**, and outputs the control signal Ctrl-C to the movement mechanism **61**. The movement mechanism **61** moves the carriage **71** by controlling the above-described motor, the reduction gear, and the like in accordance with the control signal Ctrl-C.

The head unit **20** causes the nozzles **651** to discharge the liquid. Specifically, the head unit **20** includes a discharge control circuit **200**, n driving signal output circuits **300** and n liquid discharging heads **400**. There are cases where the n driving signal output circuits **300** are respectively referred to as driving signal output circuits **300-1** to **300-*n*** for discrimination, and the n liquid discharging heads **400** are respectively referred to as liquid discharging heads **400-1** to **400-*n*** for discrimination. Further, description is performed such that a driving signal output circuit **300-*i*** (i=any of 1 to n) is provided to correspond to a liquid discharging head **400-*i***.

The discharge control circuit **200** is provided on the above-described discharge control circuit board **21**. Further, the discharge control circuit **200** generates printing data signals SI**1** to SIn, latch signals LAT**1** to LATn, change signals CH**1** to CHn, base driving signals dA**1** to dAn and dB**1** to dBn, and a clock signal SCK based on the transmission signal Tx, and outputs the generated signals to the relevant driving signal output circuits **300-1** to **300**-*n*. Further, the discharge control circuit **200** generates a reception signal Rx, which includes a signal indicative of reception of the transmission signal Tx input from the main control circuit **100**, and outputs the reception signal Rx to the main control circuit **100**.

Each of the driving signal output circuits **300-1** to **300***n* is provided on the above-described driving circuit board **30**. The driving signal output circuit **300-1** includes a first driving signal output circuit **310***a*, a second driving signal output circuit **310***b*, and a reference voltage signal output circuit **320**. The base driving signal dA**1**, which is a digital signal, is input to the first driving signal output circuit **310***a*. The first driving signal output circuit **310***a* performs digital/analog signal conversion on the base driving signal dA**1**, generates a driving signal COMA**1** by performing class D amplification on the analog signal acquired through the digital/analog signal conversion, and outputs the driving signal COMA**1** to the liquid discharging head **400-1**. Further, the base driving signal dB**1**, which is the digital signal, is input to the second driving signal output circuit **310***b*. The second driving signal output circuit **310***b* performs the digital/analog signal conversion on the base driving signal dB**1**, generates a driving signal COMB**1** by performing the class D amplification on the analog signal acquired through the digital/analog signal conversion, and outputs the driving signal COMB**1** to the liquid discharging head **400-1**. The first driving signal output circuit **310***a* and the second driving signal output circuit **310***b* may have the same configuration, and, for example, may include a class A amplification circuit, a class B amplification circuit, a class AB amplification circuit, or the like.

The reference voltage signal output circuit **320** generates a reference voltage signal VBS**1** indicative of a reference potential of the driving signals COMA**1** and COMB**1**, and outputs the reference voltage signal VBS**1** to the liquid discharging head **400-1**. For example, the reference voltage signal VBS**1** is a signal of a DC voltage having a voltage value of 6 V.

Further, the driving signal output circuit **300-1** propagates the printing data signal SI**1**, the latch signal LAT**1**, the change signal CH**1**, and the clock signal SCK, and outputs the printing data signal SI**1**, the latch signal LAT**1**, the change signal CH**1**, and the clock signal SCK to the liquid discharging head **400-1**.

The driving signal output circuits **300-1** to **300**-*n* have the same configuration, and detailed description is not repeated. That is, the base driving signals dAi and dBi are input to the driving signal output circuit **300**-*i*. Further, the driving signal output circuit **300**-*i* generates driving signals COMAi and COMBi and a reference voltage signal VBSi, and outputs the driving signals COMAi and COMBi and the reference voltage signal VBSi to the relevant liquid discharging head **400**-*i*. Further, the driving signal output circuit **300**-*i* propagates a printing data signal SIi, a latch signal LATi, a change signal CHi, and the clock signal SCK, and outputs the printing data signal SIi, the latch signal LATi, the change signal CHi, and the clock signal SCK to the relevant liquid discharging head **400**-*i*.

The liquid discharging head **400-1** includes piezoelectric elements **60** which are examples of driving elements which are driven based on the driving signals COMA**1** and COMB**1**, and causes the nozzles **651** to discharge ink by driving the piezoelectric elements **60**. The liquid discharging head **400-1** includes a plurality of discharge modules **410**. Each of the plurality of discharge modules **410** includes a driving signal selection circuit **420** and a plurality of discharge portions **600**.

The driving signal selection circuit **420** includes, for example, an integrated circuit (IC) apparatus. The printing data signal SI**1**, the latch signal LAT**1**, the change signal CH**1**, the clock signal SCK, and the driving signals COMA**1** and COMB**1** are input to the driving signal selection circuit **420**. Further, the driving signal selection circuit **420** generates a driving signal VOUT by performing selection or non-selection in accordance with the printing data signal SI**1** on the input driving signals COMA**1** and COMB**1** at timing prescribed by using the latch signal LAT**1** and the change signal CH**1**. The driving signal VOUT generated by the driving signal selection circuit **420** is supplied to one end of the piezoelectric element **60** included in each of the plurality of discharge portions **600**.

Further, the reference voltage signal VBS**1** is supplied to another end of the piezoelectric element **60** included in each of the plurality of discharge portions **600** included in the liquid discharging head **400-1**. Further, the plurality of piezoelectric elements **60** are driven based on the driving signal VOUT and the reference voltage signal VBS**1**, and cause the amount of ink to be discharged in accordance with the drive of piezoelectric elements **60**.

Here, the liquid discharging heads **400-1** to **400**-*n* have the same configuration. Specifically, the printing data signal SIi, the latch signal LATi, the change signal CHi, the clock signal SCK, and the driving signals COMAi and COMBi are input to the liquid discharging head **400**-*i*, and the driving signal VOUT is generated. Further, the generated driving signal VOUT is supplied to one end of the piezoelectric element **60** included in each of the plurality of discharge portions **600** included in the liquid discharging head **400**-*i*. Further, the reference voltage signal VBSi is supplied to one end of the piezoelectric element **60** included in each of the plurality of discharge portions **600** included in the liquid discharging head **400**-*i*. Further, the plurality of piezoelectric elements **60** are driven based on the driving signal VOUT and the reference voltage signal VBSi, and cause the ink, the amount of which corresponds to the drive of piezoelectric elements **60**, to be discharged.

3. Configuration and Operation of Liquid Discharging Head

Subsequently, a configuration and an operation of the liquid discharging head **400** will be described. When the configuration of the liquid discharging head **400** is described, description is performed while the printing data signal SIi, the latch signal LATi, the change signal CHi, the clock signal SCK, the driving signals COMAi and COMBi, and the reference voltage signal VBSi, which are supplied to the liquid discharging head **400**, are respectively referred to as a printing data signal SI, a latch signal LAT, a change signal CH, a clock signal SCK, driving signals COMA and COMB, and a reference voltage signal VBS.

FIG. **6** is a diagram illustrating a configuration of an ink discharge surface **650**, on which the plurality of nozzles **651** are formed, in the liquid discharging head **400**. FIG. **7** is a diagram illustrating a schematic configuration of one of the plurality of discharge portions **600** included in the discharge module **410**. As illustrated in FIGS. **6** and **7**, the liquid discharging head **400** includes the plurality of nozzles **651** for discharging the ink and the piezoelectric elements **60** corresponding to the respective nozzles **651**.

As illustrated in FIG. **6**, four discharge modules **410** are disposed in zigzag in the liquid discharging head **400**. In each of the discharge modules **410**, the nozzles **651**, which are provided in parallel in the Y direction, are formed in two lines in the X direction. Further, a not-shown ink channel, which communicates with the nozzles **651**, is provided in the discharge module **410**. The number of discharge modules **410** included in the liquid discharging head **400** is not limited to four.

Further, as illustrated in FIG. **7**, the discharge module **410** includes the discharge portion **600** and a reservoir **641**. The ink is introduced from an ink supply port **661** into the reservoir **641**.

The discharge portion **600** includes the piezoelectric element **60**, a diaphragm **621**, a cavity **631**, and the nozzle **651**. The diaphragm **621** is deformed in accordance with drive of the piezoelectric element **60** provided on an upper surface in FIG. **7**. The diaphragm **621** functions as a diaphragm that enlarges/reduces an internal volume of the cavity **631**. The ink is filled in the cavity **631**. Further, the cavity **631** functions as a compression chamber, the internal volume of which changes in accordance with the displacement of the diaphragm **621** due to the drive of the piezoelectric element **60**. The nozzle **651** is an opening portion which is formed in a nozzle plate **632** and which communicates with the cavity **631**. The ink stored inside the cavity **631** is discharged from the nozzle **651** in accordance with the change in the internal volume of the cavity **631**.

The piezoelectric element **60** has a structure in which a piezoelectric body **601** is interposed between a pair of electrodes **611** and **612**. In the piezoelectric body **601** having this structure, central portions of the electrodes **611** and **612** and the diaphragm **621** are bent in a vertical direction of FIG. **7** with respect to both end portions in accordance with a potential difference between the electrode **611** and the electrode **612**. Specifically, the driving signal VOUT is supplied to the electrode **611** which is the one end of the piezoelectric element **60**, and the reference voltage signal VBS is supplied to the electrode **612** which is the other end of the piezoelectric element **60**. Further, when the voltage of the driving signal VOUT decreases, the piezoelectric element **60** is driven such that a central portion is bent upward, and when the voltage of the driving signal VOUT increases, the piezoelectric element **60** is driven such that the central portion is bent downward. When the piezoelectric element **60** is bent upward, the diaphragm **621** performs displacement upward, and internal volume of the cavity **631** is enlarged. Therefore, the ink is drawn from the reservoir **641**. Further, when the piezoelectric element **60** is bent downward, the diaphragm **621** performs displacement downward, and internal volume of the cavity **631** is reduced. Therefore, the ink, the amount of which corresponds a degree of the reduction of the internal volume of the cavity **631**, is discharged from the nozzle **651**. As above, the liquid discharging head **400** includes the piezoelectric element **60**, and discharges the ink to the medium by driving the piezoelectric element **60**. The piezoelectric element **60** is not limited to the illustrated structure, and may have any structure that can discharge the ink in accordance with the displacement of the piezoelectric element **60**. Further, the piezoelectric element **60** is not limited to bending vibration, and may be configured to use longitudinal vibration.

Here, examples of waveforms of the driving signals COMA and COMB, which are the basis of the driving signal VOUT supplied to the piezoelectric element **60**, and examples of waveforms of the driving signal VOUT will be described.

FIG. **8** a diagram illustrating examples of the waveforms of driving signals COMA and COMB. As illustrated in FIG. **8**, the driving signal COMA has a waveform in which a trapezoidal waveform Adp**1** disposed in a period T**1** from rise of the latch signal LAT to rise of the change signal CH and a trapezoidal waveform Adp**2** disposed in a period T**2** from the rise of the change signal CH to the rise of the latch signal LAT. Further, when the trapezoidal waveform Adp**1** is supplied to the one end of the piezoelectric element **60**, a small amount of ink is discharged from the discharge portion **600** corresponding to the corresponding piezoelectric element **60**. When the trapezoidal waveform Adp**2** is supplied to the one end of the piezoelectric element **60**, a middle amount of the ink, which is larger than the small amount, is discharged from the discharge portion **600** corresponding to the corresponding piezoelectric element **60**.

Further, the driving signal COMB has a waveform in which a trapezoidal waveform Bdp**1** disposed in the period T**1** and a trapezoidal waveform Bdp**2** disposed in the period T**2** are continuous. Further, when the trapezoidal waveform Bdp**1** is supplied to the one end of the piezoelectric element **60**, the ink is not discharged from the discharge portion **600** corresponding to the relevant piezoelectric element **60**. The trapezoidal waveform Bdp**1** is a waveform for finely vibrating the ink near a nozzle opening portion of the discharge portion **600** to prevent an increase in the viscosity of the ink. Further, when the trapezoidal waveform Bdp**2** is supplied to the one end of the piezoelectric element **60**, the small amount of the ink is discharged from the discharge portion **600** corresponding to the corresponding piezoelectric element **60**, which is like a case where the trapezoidal waveform Adp**1** is supplied.

Here, all voltages at start timings and termination timings of the trapezoidal waveforms Adp**1**, Adp**2**, Bdp**1**, and Bdp**2** are commonly a voltage Vc. That is, each of the trapezoidal waveforms Adp**1**, Adp**2**, Bdp**1**, and Bdp**2** is a waveform that starts at the voltage Vc and ends at the voltage Vc. Further, a period Ta including the period T**1** and the period T**2** corresponds to a printing period during which dots are formed on the medium P.

Although FIG. **8** illustrates that the trapezoidal waveform Adp**1** and the trapezoidal waveform Bdp**2** have the same waveform, the trapezoidal waveform Adp**1** and the trapezoidal waveform Bdp**2** may have different waveforms. Further, in the following description, it is described that the small amount of the ink is discharged both when the trapezoidal waveform Adp**1** is supplied to the piezoelectric element **60** and when the trapezoidal waveform Bdp**2** is supplied to the piezoelectric element **60**. However, the present disclosure is not limited thereto. That is, the waveforms of the driving signals COMA and COMB are not limited to the waveforms illustrated in FIG. **8**, and signals of combinations of various waveforms may be used in accordance with a moving speed of the carriage **71** on which the liquid discharging head **400** is mounted, properties of the discharged ink, and materials of the medium P. Further, the waveforms of the driving signals COMA and COMB supplied to each of the plurality of liquid discharging heads **400** may be different from each other.

FIG. **9** is a diagram illustrating examples of waveforms of the driving signal VOUT, corresponding to a "large dot", a "middle dot", and a "small dot" formed on the medium P and "non-recording", respectively.

As illustrated in FIG. **9**, the driving signal VOUT corresponding to the "large dot" has a waveform in which, in the period Ta, the trapezoidal waveform Adp**1** disposed in the period T**1** and the trapezoidal waveform Adp**2** disposed in the period T**2** are continuous. When the driving signal VOUT is supplied to the one end of the piezoelectric element **60**, in the period Ta, the small amount of the ink and the middle amount of the ink are discharged from the discharge portion **600** corresponding to the corresponding piezoelectric element **60**. Thus, the ink lands and is coalesced, so that the large dot is formed on the medium P.

The driving signal VOUT corresponding to the "middle dot" has a waveform in which the trapezoidal waveform Adp**1** disposed in the period T**1** and the trapezoidal waveform Bdp**2** disposed in the period T**2** are continuous in the period Ta. When the driving signal VOUT is supplied to the one end of the piezoelectric element **60**, the small amount of the ink is discharged twice from the discharge portion **600** corresponding to the corresponding piezoelectric element **60** in the period Ta. Thus, the ink lands and is coalesced, so that the middle dot is formed on the medium P.

The driving signal VOUT corresponding to the "small dot" has a waveform in which the trapezoidal waveform Adp**1** disposed in the period T**1** and a waveform that is disposed in the period T**2** and is constant at the voltage Vc are continuous in the period Ta. When the driving signal VOUT is supplied to the one end of the piezoelectric element **60**, in the period Ta, the small amount of the ink is discharged from the discharge portion **600** corresponding to the corresponding piezoelectric element **60**. Thus, the ink lands, so that the small dot is formed on the medium P.

The driving signal VOUT corresponding to the "non-recording" has a waveform in which the trapezoidal waveform Bdp**1** disposed in the period T**1** and a waveform that is disposed in the period T**2** and is constant at the voltage Vc are continuous in the period Ta. When the driving signal VOUT is supplied to the one end of the piezoelectric element **60**, in the period Ta, the ink near the nozzle opening portion of the discharge portion **600** corresponding to the corresponding piezoelectric element **60** slightly vibrates, so that the ink is not discharged. Thus, as the ink does not land, no dot is formed on the medium P.

Here, the waveform that is constant at the voltage Vc is a waveform in which when none of the trapezoidal waveforms Adp**1**, Adp**2**, Bdp**1**, and Bdp**2** is selected as the driving signal VOUT, the immediately preceding voltage Vc is maintained by a capacitive component of the piezoelectric element **60**. When none of the trapezoidal waveforms Adp**1**, Adp**2**, Bdp**1**, and Bdp**2** is selected as the driving signal VOUT, the voltage Vc as the driving signal VOUT is supplied to the piezoelectric element **60**.

Next, a configuration and an operation of the driving signal selection circuit **420** that selects the waveforms of the driving signals COMA and COMB and generates the driving signal VOUT will be described. FIG. **10** is a diagram illustrating a configuration of the driving signal selection circuit **420**. As illustrated in FIG. **10**, the driving signal selection circuit **420** includes the selection control circuit **430** and a plurality of selection circuits **440**.

The printing data signal SI, the latch signal LAT, the change signal CH, and the clock signal SCK are input to the selection control circuit **430**. Further, in the selection control circuit **430**, a set of a shift register (S/R) **432**, a latch circuit **434**, and a decoder **436** is provided to correspond to each of the plurality of discharge portions **600**. That is, the driving signal selection circuit **420** includes the sets of the shift registers **432**, the latch circuits **434**, and the decoders **436**, the number of which is the same as the total number m of the corresponding discharge portions **600**.

In detail, the printing data signal SI is a signal synchronized with the clock signal SCK, and is a signal having 2 m bits totally including 2-bit printing data [SIH, SIL] for selecting any one of the "large dot", the "middle dot", the "small dot", and the "non-recording" with respect to each of the m discharge portions **600**. The printing data signal SI is held in the shift register **432** for each 2-bit printing data [SIH, SIL] included in the printing data signal SI, corresponding to the discharge portion **600**. In detail, the m stages of the shift registers **432** corresponding to the discharge portions **600** are cascade-coupled to each other, and the serially input printing data signal SI is sequentially transferred to the subsequent stage in accordance with the clock signal SCK. FIG. **10**, in order to distinguish the shift registers **432**, the shift registers **432** are sequentially represented by a first stage, a second stage, . . . , an m-th stage from an upstream where the printing data signal SI is input.

The m latch circuits **434** latch the 2-bit printing data [SIH, SIL] held by the m shift registers **432** at rising of the latch signal LAT, respectively.

FIG. **11** is a diagram illustrating decoding contents in the decoder **436**. The decoder **436** outputs selection signals S**1** and S**2** in accordance with the latched 2-bit printing data [SIH, SIL]. For example, when the 2-bit printing data [SIH, SIL] is [1, 0], the decoder **436** outputs a logic level of the selection signal S**1** as levels H and L in the periods T**1** and T**2**, and outputs a logic level of the selection signal S**2** as levels L and H in the periods T**1** and T**2** to the selection circuit **440**.

The selection circuits **440** are provided to correspond to the respective discharge portions **600**. That is, the number of selection circuits **440** included in the driving signal selection circuit **420** is the same as the total number m of the relevant discharge portions **600**. FIG. **12** is a diagram illustrating a configuration of the selection circuit **440** corresponding to one discharge portion **600**. As illustrated in FIG. **12**, the selection circuit **440** includes inverters **442***a* and **442***b* which are NOT circuits, and transfer gates **444***a* and **444***b*.

The selection signal S**1** is input to a positive control end not marked by a circle in the transfer gate **444***a*, is logically inverted by the inverter **442***a*, and is input to a negative control end marked by a circle in the transfer gate **444***a*. Further, the driving signal COMA is supplied to an input end of the transfer gate **444***a*. The selection signal S**2** is input to a positive control end not marked by a circle in the transfer gate **444***b*, is logically inverted by the inverter **442***b*, and is input to a negative control end marked by a circle in the transfer gate **444***b*. Further, the driving signal COMB is supplied to an input end of the transfer gate **444***b*. Further, output ends of the transfer gates **444***a* and **444***b* are commonly coupled to each other, and the driving signal VOUT is output.

Specifically, the transfer gate **444***a* conducts an input end and an output end when the selection signal S**1** is at the level H, and does not conduct the input end and the output end when the selection signal S**1** is at the level L. Further, the transfer gate **444***b* conducts the input end and an output end when the selection signal S**2** is at the level H, and does not conduct the input end and the output end when the selection signal S**2** is at the level L. As above, the selection circuit **440** selects the waveforms of the driving signals COMA and COMB based on the selection signals S**1** and S**2**, and outputs the driving signal VOUT.

Here, an operation of the driving signal selection circuit **420** will be described with reference to FIG. **13**. FIG. **13** is a diagram for illustrating the operation of the driving signal selection circuit **420**. The printing data signal SI is serially input in synchronization with the clock signal SCK, and is sequentially transferred in the shift registers **432** corresponding to the discharge portions **600**. Further, when the input of the clock signal SCK is stopped, the shift registers **432** hold the 2-bit printing data [SIH, SIL] corresponding to the discharge portions **600**, respectively. The printing data signal SI is input in an order corresponding to the discharge portions **600** of the m-th stage, . . . , the second stage, and the first stage of the shift registers **432**.

Further, when the latch signal LAT rises, the latch circuits **434** latch the 2-bit printing data [SIH, SIL] held in the shift registers **432** all at once, respectively. In FIG. **13**, LT**1**, LT**2**, . . . , LTm indicate the 2-bit printing data [SIH, SIL] latched by the latch circuits **434** corresponding to the shift registers **432** of the first stage, the second stage, . . . , the m-th stage.

The decoder **436** outputs the logic levels of the selection signals S**1** and S**2** in the periods T**1** and T**2**, using contents illustrated in FIG. **11**, in accordance with the size of a dot prescribed by the latched 2-bit printing data [SIH, SIL].

Specifically, when the printing data [SIH, SIL] is [1, 1], the decoder **436** sets the selection signal S**1** to levels H and H in the periods T**1** and T**2**, and sets the selection signal S**2** to levels L and L in the periods T**1** and T**2**. In this case, the selection circuit **440** selects the trapezoidal waveform Adp**1** in the period T**1**, and selects the trapezoidal waveform Adp**2** in the period T**2**. As a result, the driving signal VOUT corresponding to the "large dot" illustrated in FIG. **9** is generated.

Further, when the printing data [SIH, SIL] is [1, 0], the decoder **436** sets the selection signal S**1** to levels H and L in the periods T**1** and T**2**, and sets the selection signal S**2** to levels L and H in the periods T**1** and T**2**. In this case, the selection circuit **440** selects the trapezoidal waveform Adp**1** in the period T**1**, and selects the trapezoidal waveform Bdp**2** in the period T**2**. As a result, the driving signal VOUT corresponding to the "middle dot" illustrated in FIG. **9** is generated.

Further, when the printing data [SIH, SIL] is [0, 1], the decoder **436** sets the selection signal S**1** to levels H and L in the periods T**1** and T**2**, and sets the selection signal S**2** to levels L and L in the periods T**1** and T**2**. In this case, the selection circuit **440** selects the trapezoidal waveform Adp**1** in the period T**1**, and selects neither the trapezoidal waveform Adp**2** nor the trapezoidal waveform Bdp**2** in the period T**2**. As a result, the driving signal VOUT corresponding to the "small dot" illustrated in FIG. **9** is generated.

Further, when the printing data [SIH, SIL] is [0, 0], the decoder **436** sets the selection signal S**1** to levels L and L in the periods T**1** and T**2**, and sets the selection signal S**2** to levels H and L in the periods T**1** and T**2**. In this case, the selection circuit **440** selects the trapezoidal waveform Bdp**1** in the period T**1**, and selects neither the trapezoidal waveform Adp**2** nor the trapezoidal waveform Bdp**2** in the period T**2**. As a result, the driving signal VOUT corresponding to "non-recording" illustrated in FIG. **9** is generated.

As above, the driving signal selection circuit **420** selects waveforms of the driving signals COMA and COMB based on the printing data signal SI, the latch signal LAT, the change signal CH, and the clock signal SCK, and outputs the driving signal VOUT. In other words, the driving signal selection circuit **420** controls supply of the driving signals COMA and COMB to the piezoelectric element **60**.

4. Details of Electrical Connection of Main Control Circuit and Discharge Control Circuit

Here, details of configurations of the head control unit **10** and the head unit **20** and details of signals propagated between the head control unit **10** and the head unit **20** will be described.

FIG. **14** is a diagram illustrating configurations of the head control unit **10** and the head unit **20**. As illustrated in FIG. **14**, the head control unit **10** includes the main control circuit **100** which includes a conversion circuit **110** and a photoelectric conversion circuit **130**. Further, the head control unit **10** and the head unit **20** are connected through optical cables **170***a* and **170***b* in the cable **82** for communication. The optical cables **170***a* and **170***b* may be, for example, an optical fiber cable.

The conversion circuit **110** converts the image signal PDATA, which is supplied from a not-shown host computer or the like, into an image signal ePDATA**1** which is an electric signal. Further, the conversion circuit **110** outputs the image signal ePDATA**1** to the photoelectric conversion circuit **130**. Further, a response signal eREP**2** is input to the conversion circuit **110**. The response signal eREP**2** is a signal which indicates that the image signal ePDATA**1** output by the conversion circuit **110** is normally propagated to the relevant head unit **20**. Here, an image signal oPDATA corresponds to the transmission signal Tx illustrated in FIG. **1**, and a response signal oREP corresponds to the reception signal Rx illustrated in FIG. **1**.

The photoelectric conversion circuit **130** includes an E/O circuit **131** and an O/E circuit **132**. The E/O circuit **131** includes a light emitting element or the like, and converts the input electric signal into the optical signal. Specifically, the image signal ePDATA**1**, which is the electric signal, is input to the E/O circuit **131**. Further, the E/O circuit **131** converts the image signal ePDATA**1** into the image signal oPDATA which is the optical signal. Further, the O/E circuit **132** includes a light receiving element or the like, and converts the input optical signal into the electric signal. Specifically, the response signal oREP, which is the optical signal, is input to the O/E circuit **132**. Further, the O/E circuit **132** converts the response signal oREP into the response signal eREP**2** which is the electric signal.

Here, the conversion circuit **110**, which converts the image signal PDATA including image data input from the host computer provided on the outside of the liquid discharging apparatus **1** into the image signal ePDATA**1** that is the electric signal, is an example of a first conversion circuit, the image signal ePDATA**1** is an example of a first electric signal, and a process of converting the image signal PDATA into the image signal ePDATA**1** by the conversion circuit **110** is an example of a first conversion process. Further, the photoelectric conversion circuit **130**, which converts the image signal ePDATA**1** that is the electric signal into the image signal oPDATA that is the optical signal, is an example of a first photoelectric conversion circuit.

The head unit **20** includes a discharge control circuit **200** including a conversion circuit **210** and a photoelectric conversion circuit **230**.

The photoelectric conversion circuit **230** includes an O/E circuit **231** and an E/O circuit **232**. The O/E circuit **231** includes the light receiving element or the like, and converts the input optical signal into the electric signal. Specifically, the image signal oPDATA, which is the optical signal, is input to the O/E circuit **231**. Further, the O/E circuit **231** converts the image signal oPDATA into an image signal ePDATA**2** which is the electric signal. Further, the E/O circuit **232** includes a light emitting element or the like, and converts the input electric signal into the optical signal. Specifically, a response signal eREP**1**, which is the electric signal, is input to the E/O circuit **232**. Further, the E/O circuit **232** converts the response signal eREP**1** into the response signal oREP which is the optical signal.

Discharge information DI of the liquid discharging head **400** is input to the conversion circuit **210**. Further, the conversion circuit **210** converts the image signal ePDATA**2** into the printing data signal SI, the latch signal LAT, the change signal CH, the clock signal SCK, and the base driving signals dA and dB based on the discharge information DI. Further, the conversion circuit **210** generates the response signal eREP**1**, which indicates that the image signal ePDATA**2** is normally received, and outputs the response signal eREP**1** to the E/O circuit **232**.

Here, the photoelectric conversion circuit **230**, which converts the optical signal that is input from the head control unit **10** into the image signal ePDATA**2**, is an example of a second photoelectric conversion circuit, and the image signal ePDATA**2** is an example of a second electric signal. Further, the conversion circuit **210**, which converts the image signal ePDATA**2** that is the electric signal into the printing data signal SI, the latch signal LAT, the change signal CH, and the clock signal SCK, is an example of a second conversion circuit, at least one of the printing data signal SI, the latch signal LAT, the change signal CH, and the clock signal SCK is an example of a discharge control signal for controlling discharge of a liquid from the nozzles **651**, and a process for converting the image signal ePDATA**2** into the discharge control signal is an example of the second conversion process.

The image signal ePDATA**1** acquired before being converted into the optical signal in the main control circuit **100** may be the same signal as the image signal ePDATA**2** which is converted from the optical signal in the discharge control circuit **200**. Further, the response signal eREP**1** acquired before being converted into the optical signal in the discharge control circuit **200** may be the same signal as the response signal eREP**2** which is converted from the optical signal in the main control circuit **100**.

5. Generation of Discharge Control Signal

As described above, in the liquid discharging apparatus **1** of the exemplary embodiment, the image signal PDATA, which includes the image data input from the host computer, is converted into the discharge control signal corresponding to each of the nozzles **651** in a process of being propagated in the conversion circuit **110**, the photoelectric conversion circuit **130**, the photoelectric conversion circuit **230**, and the conversion circuit **210**, and is output from the discharge control circuit **200**.

Here, a conversion process of converting the image signal PDATA, which includes the image data input from the host computer, into the discharge control signal, which corresponds to each of the nozzles **651**, will be described with reference to FIGS. **14** and **15**. FIG. **15** is a flowchart illustrating a conversion processing method for converting the image signal PDATA into the discharge control signal.

In the liquid discharging apparatus **1** according to the exemplary embodiment, the conversion circuit **110** converts the image signal PDATA into the image signal ePDATA**1** without depending on the discharge information DI of the ink discharged from the liquid discharging head **400**, and the conversion circuit **210** converts the image signal ePDATA**2** into the discharge control signal by using the discharge information DI.

Specifically, as illustrated in FIG. **15**, the image signal PDATA, which includes the image data, is input from the host computer to the main control circuit **100** of the liquid discharging apparatus **1** (step S**100**).

Further, the image signal PDATA, which is input to the main control circuit **100**, is input to the conversion circuit **110**. Further, the conversion circuit **110** performs a color conversion process on the image signal PDATA (step S**110**). The color conversion process is a process of converting color information corresponding to a hue of the image data included in the image signal PDATA into the color information corresponding to a hue of the liquid which is discharged from the nozzles **651**. For example, when the image data included in the image signal PDATA is realized by combining grayscale values of red, green, and blue, the color conversion process is a process of converting the image data into image data which is realized by combining grayscales of cyan, magenta, yellow, and black of a color of the ink used in the liquid discharging apparatus **1**. It is possible to rapidly perform the color conversion process by referring to a 3-dimensional numerical table called a color conversion table. The ink used in the liquid discharging apparatus **1** is not limited to the above described ink, and, for example, light cyan or light magenta may be included.

Next, the conversion circuit **110** performs a half-tone process with respect to the image signal PDATA on which the color conversion process is performed (step S**120**). The half-tone process is a binarization process of converting the image signal PDATA into a signal which indicates whether or not the ink corresponding to a pixel included in the image data is discharged, and is a process of determining a position of the medium to which the ink is discharged in order to reproduce grayscale information of the input image signal PDATA. The binarization process may include a process of determining the amount of ink to be discharged to the medium, in addition to a process of determining whether or not the ink is discharged with respect to the-above described medium. Further, the half-tone process may be performed through, for example, dithering using a dither mask.

Further, the image signal PDATA, on which the color conversion process and the half-tone process are performed, is output as the image signal ePDATA**1** from the conversion circuit **110**. That is, the conversion circuit **110** outputs a signal, which is acquired by performing the binarization process on the image signal PDATA, as the image signal ePDATA**1**. Further, the image signal ePDATA**1** is supplied to the head unit **20** after being converted into the image signal oPDATA, which is the optical signal, in the photoelectric conversion circuit **130**.

Here, the above-described color conversion process and the half-tone process are performed with respect to the image signal PDATA in accordance with a predetermined arithmetic operation. That is, the color conversion process and the half-tone process are processes which do not rely on the discharge information DI of the ink discharged from the liquid discharging head **400**, and the conversion circuit **110** performs the process which does not rely on the discharge information DI. Further, the conversion circuit **110** may perform only the color conversion process and may output a signal, which is acquired by performing the color conversion process on the image signal PDATA, as the image signal ePDATA. However, as illustrated in the exemplary embodiment, it is preferable that the conversion circuit **110** performs the process up to the half-tone process, and outputs a signal, which is acquired by performing the color conversion process and the half-tone process on the image signal PDATA, as the image signal ePDATA**1**. As will be described later, the head unit **20** converts the image signal ePDATA**2** into the discharge control signal corresponding to the plurality of nozzles **651** included in the liquid discharging head **400**. Therefore, a load of the process performed in the head unit **20** becomes large, compared to the process performed by the head control unit **10**. As illustrated in the exemplary embodiment, when a larger number of processes, which are possible without using the discharge information DI, are performed in the head control unit **10**, it is possible to reduce the load of the process in the head unit **20**.

The image signal oPDATA supplied to the head unit **20** is input to the conversion circuit **210** after being converted into the image signal ePDATA**2**, which is the electric signal, in the photoelectric conversion circuit **230**. Further, the conversion circuit **210** performs a nozzle complement process with respect to the image signal ePDATA**2** (step S**130**). When a nozzle **651** which is not capable of normally discharging the ink exists in the plurality of nozzles **651** included in the liquid discharging head **400**, the nozzle complement process is a process of complementing the ink to be originally discharged from the nozzle **651**, from which the ink is not discharged, by adjusting the discharge amount of the ink which is discharged from another nozzle **651** provided in the vicinity of the relevant nozzle **651**. Specifically, information, which indicates whether or not the liquid is discharged from the nozzles **651**, is input as the discharge information DI to the conversion circuit **210**. In other words, the discharge information DI includes information, which indicates whether or not the liquid is discharged from the nozzles **651**. Further, based on the discharge information DI, a process of determining whether or not the nozzle **651**, which is not capable of normally discharging the ink, exists is performed. Further, when the nozzle **651** from which the ink is not discharged exists, the process of adjusting the discharge amount of the ink discharged from another nozzle **651** provided in the vicinity of the relevant nozzle **651** is performed.

Here, as the discharge information DI which indicates whether or not the nozzle **651** which is not capable of normally discharging the ink exists, there are provided, for example, a method for detecting a waveform, which is generated after discharging the ink, of a residual vibration of the piezoelectric elements **60**, a method for causing ink drops discharged from the nozzles **651** to be irradiated with laser light and detecting a change in the amount of light of the laser light, and the like.

Further, the conversion circuit **210** performs an interlace process with respect to the image signal ePDATA**2** (step S**140**). The interlace process is a process of performing conversion on pixel information included in the input image signal ePDATA**2** in order corresponding to the nozzles **651** included in the liquid discharging head **400**. For example, when the image data included in the input image signal ePDATA**2** is the pixel information arranged in a direction intersecting with respect to a transport direction of the medium P and columns of the nozzles included in the liquid discharging head **400** are provided to be parallel to the transport direction of the medium P, the interlace process includes a vertical conversion process of rearranging the pixel information included in the image signal ePDATA**2** in order corresponding to the nozzles **651**. Further, in the liquid discharging head **400** in which one pseudo nozzle column is formed by a plurality of nozzle columns, when the nozzles **651** provided in different nozzle columns are provided in positions, which overlap in a movement direction of the carriage **71**, the interlace process includes a process of correcting the discharge amount of the ink in each of the overlapping nozzles **651**.

Further, the conversion circuit **210** performs a pixel shift process with respect to the image signal ePDATA**2** (step S**150**). The pixel shift process is a process of correcting discharge timing of the ink which is discharged from the nozzles **651** based on a difference between an ideal landing position of the medium P, which is desired to make the ink discharged from the nozzles **651** land, and a real landing position on which the ink actually lands. Specifically, the liquid discharging head **400** acquires information of the real landing position using image recognition using a camera or the like, hue recognition based on a color of an image formed on the medium, or the like. Further, the discharge information DI, which includes the difference between the real landing position and the ideal landing position, is input to the conversion circuit **210**. The conversion circuit **210** performs a process of correcting the discharge timing of the ink which is discharged from the nozzles **651** based on the input discharge information DI.

As above, the conversion circuit **210** converts the image signal ePDATA**2** from a signal corresponding to the pixel included in the image data into the signal corresponding to each of the nozzles **651**. In other words, the conversion circuit **210** includes a nozzle correspondence process of performing conversion into a signal which indicates whether or not the ink is discharged from the nozzles **651** in correspondence to the nozzles **651**. Steps S**130**, S**140**, and S**150** illustrated in FIG. **15** may be performed in any order.

After the nozzle complement process, the interlace process, and the pixel shift process, which are described above, are performed, the conversion circuit **210** generates and outputs the printing data signal SI, the latch signal LAT, the change signal CH, and the clock signal SCK, as the discharge control signal (step S**160**).

6. Effects

The liquid discharging apparatus **1** of the above-described exemplary embodiment includes: the head control unit **10** including the conversion circuit **110** that converts the image signal PDATA including the image data input from the outside into the image signal ePDATA, and the photoelectric conversion circuit **130** that converts the image signal ePDATA into the image signal oPDATA which is the optical signal; and the head unit **20** including the photoelectric conversion circuit **230** that converts the image signal oPDATA, which is the optical signal, into the image signal ePDATA**2**, the conversion circuit **210** that converts the image signal ePDATA into the discharge control signal for controlling the discharge of the liquid from the nozzles **651**, and the liquid discharging head **400** that discharges the liquid from the nozzles **651** by driving the piezoelectric elements **60** based on the discharge control signal. That is, in the liquid discharging apparatus **1**, the discharge control signal for controlling the discharge of the ink from the liquid discharging head **400** is propagated as the optical signal between the head control unit **10** and the head unit **20**.

Further, the conversion circuit **110** performs the process of converting the image signal PDATA into the image signal ePDATA**1** without depending on the discharge information DI of the liquid discharged from the liquid discharging head **400**, and the conversion circuit **210** performs the process of converting the image signal ePDATA**2** into the discharge control signal using the discharge information DI. That is, the conversion circuit **210**, which is included in the liquid head unit **20** that includes the discharging head **400**, performs a conversion process using the discharge information DI of the ink discharged from the liquid discharging head **400**, and the conversion circuit **110**, which is included in the head control unit **10** that does not include the liquid discharging head **400**, performs a conversion process which does not rely on the discharge information DI of the ink discharged from the liquid discharging head **400**. Therefore, it is not necessary to propagate the discharge information DI with respect to the conversion circuit **110** which performs the process that does not rely on the discharge information DI of the ink. Accordingly, it is not necessary to convert the discharge information DI of the ink into the optical signal in order to generate the discharge control signal for controlling drive of the piezoelectric elements **60**. Therefore, it is possible to reduce time which is required to generate the discharge control signal, and thus it is possible to improve a control speed of the liquid discharging apparatus **1**.

Although the exemplary embodiments and the modification examples have been described above, the present disclosure is not limited to these exemplary embodiments, and may be carried out in various modes without departing from the gist thereto. For example, the above-described embodiments can be combined appropriately.

The present disclosure includes substantially the same configuration (for example, a configuration having the same function, method, and result or a configuration of the same purpose and effect) as the configuration described in the exemplary embodiment. Further, the present disclosure includes configurations in which nonessential parts of the configurations described in the embodiments are replaced. Further, the present disclosure also includes configurations that have the same effects as those of the embodiments or configurations that can achieve the same objects as those of the embodiments. Further, the present disclosure includes a configuration obtained by adding a Known technique to the configurations described in the embodiments.

What is claimed is:

1. A liquid discharging apparatus comprising:

a head unit that discharges a liquid from a nozzle; and

a head control unit that controls an operation of the head unit, wherein

the head control unit includes

a first conversion circuit that converts an image signal, which includes image data input from an outside, into a first electric signal, and

a first photoelectric conversion circuit that converts the first electric signal into an optical signal,

the head unit includes

a second photoelectric conversion circuit that converts the optical signal into a second electric signal,

a second conversion circuit that converts the second electric signal into a discharge control signal for controlling discharge of a liquid from the nozzle, and

a liquid discharging head that includes a driving element, which is driven based on the discharge control signal, and that discharges a liquid from the nozzle in accordance with drive of the driving element,

the first conversion circuit performs a first conversion process of converting the image signal into the first electric signal without depending on a discharge information of a liquid discharged from the liquid discharging head,

the second conversion circuit performs a second conversion process of converting the second electric signal into the discharge control signal by using the discharge information, and

the discharge information includes information which indicates whether the nozzle is not capable of normally discharging liquid.

2. The liquid discharging apparatus according to claim **1**, wherein

the first conversion process includes a color conversion process of converting color information corresponding to a hue of the image data included in the image signal into color information corresponding to a hue of a liquid discharged from the nozzles.

3. The liquid discharging apparatus according to claim **1**, wherein

the first conversion process includes a binarization process of converting the image signal into a signal which indicates whether or not a liquid corresponding to a pixel included in the image data is discharged.

4. The liquid discharging apparatus according to claim **3**, wherein

the first electric signal is a signal acquired by performing the binarization process on a signal based on the image signal.

5. The liquid discharging apparatus according to claim **1**, wherein

the second conversion process includes a nozzle correspondence process of converting the second electric signal into a signal which indicates whether or not a liquid corresponding to the nozzle is discharged.

6. A head control unit, which controls an operation of a head unit that discharges a liquid from a nozzle, the head control unit comprising:

a first conversion circuit that converts an image signal, which includes image data input from an outside, into a first electric signal; and

a first photoelectric conversion circuit that converts the first electric signal into an optical signal, wherein

the head control unit receives discharge information of a liquid discharged from the nozzle,

the first conversion circuit performs a first conversion process of converting the image signal into the first electric signal without depending on the discharge information, and

the discharge information includes information which indicates whether the nozzle is not capable of normally discharging liquid.

7. A head unit, which discharges a liquid from a nozzle based on a signal input from a head control unit, the head unit comprising:

a second photoelectric conversion circuit that receives an optical signal input from the head control unit, and converts the optical signal into a second electric signal;

a second conversion circuit that converts the second electric signal into a discharge control signal for controlling discharge of a liquid from the nozzle; and

a liquid discharging head that includes a driving element, which is driven based on the discharge control signal, and that discharges a liquid from the nozzle in accordance with drive of the driving element, wherein

the second conversion circuit performs a second conversion process of converting the second electric signal into the discharge control signal by using a discharge information of a liquid discharged from the liquid discharging head, and

the discharge information includes information which indicates whether the nozzle is not capable of normally discharging liquid.

* * * * *